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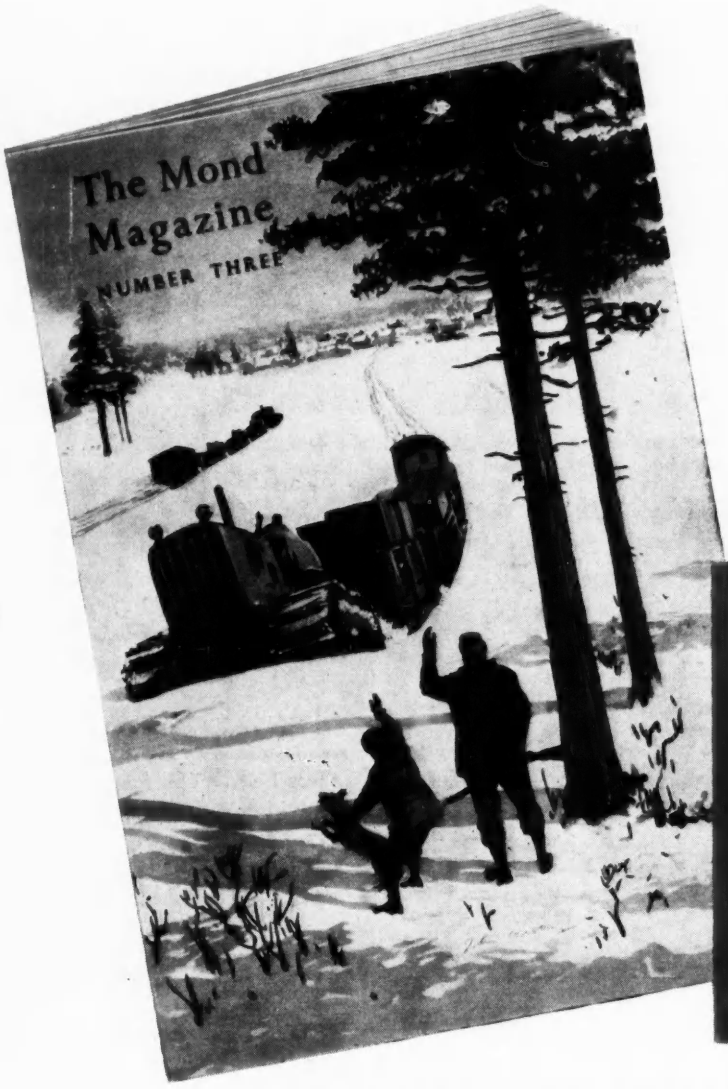

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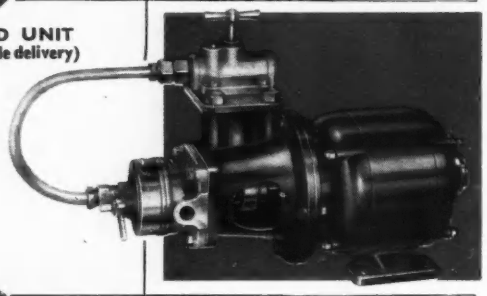

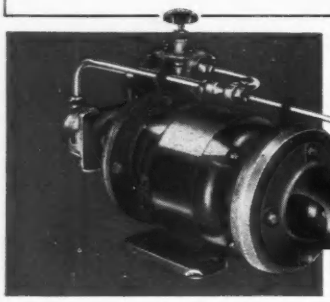

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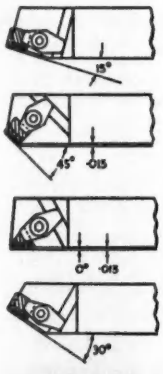

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INTERNATIONAL GEOPHYSICAL YEAR

Last Monday there began what scientists have termed the International Geophysical Year. It will in fact extend over eighteen months to December 31, 1958. For scientists it will be an exciting period, even if for many of them it will mean an exacting eighteen months of hard and continuous observation with very little chance of perceiving or even speculating upon the way in which the various observations will fit together to support or to disprove hypotheses. Even for laymen the affair is not without excitement. For it is very encouraging when, politically, the world is divided into hostile blocks and when in many regions appeals to nationalism are being pressed to extremes, to find scientists all over the world co-operating to improve their knowledge of the earth and its relationship with the sun ; or, as scientists would perhaps prefer to put it, of studying the effects on the earth of phenomena occurring on the surface of the sun. Even the sun itself has evinced a desire to co-operate ! In this the very first week of I.G.Y. a notable flare has occurred on its surface with consequent effects already under intensive observation on the earth. As if to emphasise that scientific co-operation extends across the Iron Curtain, first reports of the occurrence seem to have come from Russian observers.

Last week the Royal Society held its annual conversazione, at which, as usual, there were many scientific exhibits. This year those exhibits were particularly notable because they all related to the work that will be done during the year. Naturally, we looked at those exhibits, talked to the scientists in charge and read a book published by the Royal Society about the U.K. contribution to the I.G. Year, with the idea of discovering to what extent engineers have made contributions to, and how they can expect to benefit from, the Year. In the contributions that they are making engineers can certainly take great pride. Many of the instruments used will be the productions of engineering firms and some of them, such as the Jodrell Bank radio-telescope, are very notable as engineering structures ; and, in addition, there is much other equipment—the tractors that have already proved themselves in service in the Antarctic perhaps deserve special mention—without which scientists could neither have reached remote observation points nor maintained themselves there in reasonable comfort. Particular pride can be taken in the development of rockets. In this field the U.S. project for establishing several earth satellites in orbits 200 miles and more above the surface of the earth has particularly captured the public's attention and much has been published in this and other journals about it. But that project should not be allowed to overshadow the important British contribution in the rocket field. Just in time for I.G.Y. there has been developed at Woomera the "Skylark" upper-atmosphere rocket. One of these rockets has already risen 50 miles above the earth's surface and it is confidently expected that on future firings rockets of this design will reach heights of 90 or 100 miles. "Skylark" rockets will be used to help to determine the temperature, pressure and density of the atmosphere at great heights, the wind distribution, the nature of the processes which give rise to airglow, and certain facts about the behaviour of the ionosphere.

But the benefits to engineers, from the Year, seem at a first hearing disappointing. Only electronic engineers are likely to benefit directly through the knowledge about the ionosphere expected to be derived from eighteen months' continuous and worldwide observation of it. For engineers in other fields, benefits are likely to be indirect and small. Furthermore, so great will be the mass of detailed information collected that it will probably be years before it can be sufficiently digested for engineers to apply it. Aircraft are now flying at such heights that some of the information about the upper air of the atmosphere may eventually prove helpful for navigation and thus indirectly have an influence on aircraft design and instrumentation. One of the subjects to be studied relates to sea waves and another to the fluctuation of mean sea level. Civil engineers responsible for harbour and sea defence works may expect

to benefit. It is hoped that measurements made during the year will make possible more accurate determinations of the relative positions of continental land masses. There is little advantage to navigators to be expected, as possible errors even to-day are unlikely to exceed 100 metres. But this work will be tied up with the more accurate measurement of time and the results may prove applicable for the control of precision standards of frequency, a matter of importance in electronics. Nuclear engineers may find food for thought in worldwide measurements to be made of nuclear radiation. No doubt other examples of benefits to engineers could be added to the list. But it is all rather small beer. Yet it would be very short sighted to discuss the I.G. Year as something not particularly interesting or exciting for engineers. It is true that no great benefits to be derived from it can be immediately perceived. But then who before the war thought there was much of engineering interest in the work of Lord Rutherford ? There may still be great fundamental discoveries to be made in science. Notably a great deal remains mysterious about cosmic rays. To quote from the Royal Society's book, " So long as the mechanism which is responsible for providing particles of high energy is not known there is the possibility that this ignorance is related to the ignorance of some major process or some basic physical effect in the universe." Who would dare to assert that there are no more fundamental scientific discoveries still to be made which engineers will be able to apply for the benefit of mankind ? Observations made during the I.G. Year may provide the clue to their discovery.

MANCHESTER UNIVERSITY'S RADIO TELESCOPE

Professor Lovell has the lecturers' gift of imparting enthusiasm to his listeners. It was fascinating to hear his dissertation, at the Press visit last week to the Jodrell Bank experimental station, of the researches which will be undertaken with the new radio telescope. An ample store of fundamental cosmological knowledge is likely to be gained from its use. It will be possible to make a count of radio sources at great distances—as great as 10^9 light years away where the velocity of recession is a significant fraction of the speed of light—and hence to obtain experimental evidence with an important bearing on the two theories at present debated about the nature of the universe—the " continuous creation " theory and the " exploding super-dense bubble " theory. Other studies will, of course, be carried out, but the central interest lies in the fact that radio astronomy has now reached a stage where it promises to reveal as much about the universe as did the large optical telescopes when they were first used.

All of this is now of special interest to the engineer, be he civil, mechanical or electrical, and even should he be entirely uninterested in the vastness and complexity of the universe. For as the pure scientist's realms expand, he tends to rely more upon the engineer to design and build his instruments. The whole science of radio astronomy demonstrates this fact, for its progress springs largely from wartime advances in radar techniques. And the latest instruments serving this science are examples of engineering in the grand manner. An interferometer under construction at Cambridge is to be steerable in declination, and will not be able to " track " ; it is nevertheless of considerable size. The more elaborate design of the Jodrell Bank telescope, together with stringent requirements for accuracy of shape, render its completion an engineering achievement of note. We were particularly struck by the broad scope of the general design problem which the telescope presented, for it embodies problems of civil, mechanical and electrical engineering, implying a wide, generalised knowledge at least in the early stages of design. Specialisation came later. Another noteworthy point was the manner in which more or less standard engineering components have been adapted to the special needs of the radio telescope. The most unusual engineering problem was probably the structure itself, and the consulting engineer considered that a steel framework of such complexity and precision (tolerances were less than $\frac{1}{4}$in) was unequalled and reflected great credit in British workmanship.

We learn from the *Manchester Guardian* that the telescope is costing more than was estimated, and arrangements have still to be made to find part of the money. Apparently this situation can be attributed to improvements over the original design ; wavelengths down to 20cm (the hydrogen line at 21cm is assuming great importance in these studies) are to be detected, as against the original lower figure of about 1m, with a correspondingly severe increase in accuracy of construction. But it should not be a cause for criticism if enthusiasm should outrun its purse strings in a project of this nature. The cost of armaments, and, indeed, the losses of nationalised industries, both fantastically large compared with the sum needed for a research project such as this one, are accepted without a murmur. Surely the economy of our land is not so tight that it cannot afford to finance generously its more meritorious researches.

ADVANCED SPONSORED RESEARCH INTO BOILER CIRCULATION THEORY

Even before the war, when, by present-day standards, steam pressures and temperatures in boilers (other than those of a somewhat experimental character) were relatively moderate, it was becoming clear that a great deal remained unknown about what goes on in a boiler tube, and the merits of controlled circulation boilers were being hotly debated as against those of natural circulation boilers. No doubt many manufacturers did a certain amount of research on these matters for themselves and some work was also done at universities. None of this work, however, really got down to fundamentals. Since the war steam pressures and temperatures, even for more or less standard products, have been pressed up above 1000 lb per square inch and 1000 deg. Fah., and manufacturers have been willing to supply boilers for very substantially higher conditions. Within the foreseeable future boilers may regularly be built for critical pressure conditions. In these circumstances, as was revealed shortly before we went to press, the Water-Tube Boilermakers' Association decided to sponsor a research for the benefit of its members as a whole, and, its attention having been drawn in 1950 to certain work being done at Cambridge University (the results of which were published in 1951 at the general discussion on heat transfer at the Institution of Mechanical Engineers in a paper on " Research into the Fundamentals of Boiler Circulation Theory"), an approach was made to that university. A research contract was agreed upon in 1951. The primary object of the research thus begun, and whose results are now beginning to become available to members of the Association, was to establish experimental data relating to the pressure drop and flow conditions of a steam/water mixture flowing along heated and unheated pipes at pressures up to the critical. Studies are being made of the effect of several variables, including pressure, heat input rate, internal diameter and inclination of the test section, the velocity of the water entering the heated test section, and the dryness fraction of the emergent steam/water mixture. We hope in one or other of our next two issues to give fuller particulars of the experimental apparatus. For many problems were encountered in devising satisfactory equipment and, quite apart from the value of the research itself, there is a great deal of interest to be found in the designs adopted for induction heaters, for differential thermocouples and for differential pressure manometers for use at very high pressures. In the meanwhile, we congratulate the Association for sponsoring so important a research. We understand that certain results of considerable interest have already been obtained and that arrangements are being made for their publication in due course. It is particularly gratifying that no undue secrecy is to be observed. For the research is of so fundamental a character that its results may be applicable in fields other than that of boiler manufacture alone.

A Seven Day Journal

British Industries Fair

ON Thursday of last week, the President of the Board of Trade, the Rt. Hon. Sir David Eccles, received a deputation from the Birmingham Chamber of Commerce to discuss the future of the British Industries Fair at Castle Bromwich. The president of the Federation of British Industries, Sir Hugh Beaver, and officials of the F.B.I. were also present. The deputation was led by the president of the chamber, Mr. R. P. S. Bache. The deputation, explained the president, was in favour of placing the fair on an international basis. In support of such a project he referred to the consequences, were this country to join a European Free Trade Area. The chamber felt that in those circumstances a general international trade fair, comparable with those held on the Continent, ought to be held here. It might, however, be something of an anomaly were such a fair to become the sole responsibility of the Birmingham Chamber of Commerce. He further explained that the chamber had decided not to hold the fair at all in 1958 as it would, in any case, be impracticable to organise an international fair in the time available. Sir David Eccles said that, in his view, the question of internationalisation in future years must depend primarily on the attitude of British industry, and the president of the F.B.I. agreed to make further inquiries on this point.

Changes in Organisation on Western Region of British Railways

A NUMBER of changes in the organisation of the mechanical and electrical, carriage and wagon, and motive power departments of the Western Region of British Railways came into effect on July 1. Under these changes the chief mechanical and electrical engineer, in addition to his existing responsibilities for mechanical and electrical engineering relating to locomotives and outdoor machinery, assumed the responsibilities of the carriage and wagon engineer. The positions of carriage and wagon engineer, at Swindon, and district outdoor carriage and wagon engineer at London, Swindon and Cardiff, have been abolished.

The motive power superintendent has been redesignated running and maintenance officer, and is responsible to the chief operating superintendent for all the functions of the motive power department and also for the serviceability and maintenance of carriages and wagons, while under the control of the operating department. District motive power superintendents have been redesignated district running and maintenance officers.

Data Processing

THE Society of Instrument Technology is setting up a section whose special interest will be data-processing systems. The section is to obtain papers reviewing the rather scattered literature of the subject, and will provide a discussion centre for designers and users. The following papers are scheduled for the section's initial meetings : Thursday, October 10—" A System for Handling Wind-Tunnel Data," by J. F. M. Scholes (R.A.E.) ; Thursday, November 14—" A Digital Plotting Table," by J. Morrison (Dobbie, McInnes, Ltd.) ; Tuesday, January 28—" Digital Codes and Coding," by M. P. Atkinson (N.P.L.) ; Tuesday, April 29—" Scanning and Logging," papers by D. H. Whiting and J. Dunkley (I.C.I.), and J. Churchill (Sunvic Controls, Ltd.). All members of the society may join the section and the papers on data processing will be published in the society's quarterly *Transactions*. Further information is available from the Secretary, S.I.T., 20, Queen Anne Street, London, W.1.

The Engineer
100 Years Ago

(JULY 3, 1857)

" RAILWAY ACCIDENTS "

" A very few months have elapsed since we felt ourselves compelled to call attention to the subject of railway accidents, with a view of proving that Parliamentary interference was necessary in order to compel the adoption of measures to guard against the frequent occurrence of these sad calamities, and such as would ensure greater safety to the public. Upon that occasion we ventured to point out a few of the numerous regulations which it appeared to us Parliament might reasonably enforce, and further endeavoured to show that very few accidents occurred which might not be prevented by a moderate degree of attention, and the adoption of known means of safety. . . .

" In endeavouring to arrive at the causes which prevent railway authorities from adopting the means for the prevention of accidents which have from time to time been pointed out to them, it seems to us that they do not usually deny that those means would, under special circumstances, prevent accidents, but that they would do so only at such remote intervals as to render their adoption disproportionately expensive for the good which would result from them. Now this is precisely where legislative interference is necessary, that is, to convince railway companies that it is worth while to take precautionary measures, although it were proved that the accidents prevented were few and far between. By not adopting means of safety where the traffic can ordinarily be carried on without accident, railway managers do in fact, set the value of human lives at nought, considering the possible loss of them as of little importance against the certain loss as they suppose of so many shillings or pounds as the case may be ; although one would suppose from the severe lessons juries have lately taught them would have made them look closer into the best ways of saving money, even if their own feelings of humanity did not dictate to them the necessity of using their utmost endeavours to protect the lives of their passengers at any reasonable outlay."

Sponsored Research

ON Tuesday last, the Fulmer Research Institute held an open day. The Institute is a sponsored research laboratory—literally a laboratory for hire—and during its first ten years' activity has carried out investigations for some 700 British firms. About one-half of the work undertaken is for Government departments and nationally owned undertakings, while one dollar in every pound of income is from United States sponsors.

Much of the current work of the laboratory will be familiar to readers from our account of the open day in 1952 (page 496, October 10, 1952). Other investigations of topical interest concerned methods of working the ductile chromium materials that are regarded as potentially valuable for high-temperature applications. It was found possible to form the metal by extrusion, the chromium being embedded in mild steel, the billet extruded with the use of glass lubrication, and the steel turned and dissolved away to leave a finished bar of high purity. Aluminium bearings with high tin contents have also been the subject of promising investigation, and a method of bonding these alloys to steel has opened up the possibility of using them in highly stressed mechanisms.

Colour Photography

A FILM of unusual and appealing beauty has recently been prepared. The first of a series of three films on " High Speed Flight," " Approaching the Speed of Sound " depicts and explains the onset of compressibility effects, stopping just short of the reasons for separation and the increased speed of propagation of larger disturbances. For all who do not have the opportunity to experiment in a high-subsonic wind tunnel the experiments portrayed will be of great value ; the majority are visualised in colour, the knife-edge of classical schlieren technique being replaced by a three-colour filter. The resulting pictures of flow are not only of technical but also of æsthetic value. It may be recalled that these pictures were used by Sir William Farren in his address, " The Aerodynamic Art " (Seven Day Journal, May 25, 1956). There are also many sequences of air-to-air photography, including aerobatics by " Javelin " and " Vulcan " deltas, refuelling of a " Stratofortress " with under-wing tanks by a " Stratotanker," and close-ups of a " Canberra." Many of the aircraft are infrequently seen on films, such as the " Draken," " Lansen," " Gnat," Tu. 104 and " Jet Stratoliner." Even more unusual are cloudscapes photographed during aerobatics and cockpit interiors in a " Canberra " encountering buffeting. The film has been made by the " Shell " Film Unit.

Railway Modernisation

AN exhibition entitled " Modern Railway Travel Exhibition," showing some of the new passenger equipment which has been developed under the modernisation and re-equipment plan for the railways, was opened by Mr. Harold Watkinson, Minister of Transport and Civil Aviation, at Battersea Wharf Goods Depot, London, on Friday, June 28. The exhibition was arranged by the British Transport Commission to give people an opportunity of examining the latest examples of passenger rolling stock and diesel traction now in use or shortly to be introduced throughout the country as part of the modernisation programme. Amongst the exhibits were diesel locomotives, including the English Electric "Deltic" prototype, passenger carriages, catering vehicles, sleeping cars, diesel trains, an instruction train for training staff in diesel operation, a waiting room, an enquiry office, a mechanised ticket office, a lounge buffet and refreshment trolleys.

In a speech introducing the Minister of Transport, Sir Brian Robertson, chairman of the British Transport Commission, said that by the end of 1962 25,000 coaching vehicles would have been replaced by some 20,000 new ones. The value of railway modernisation to British industry could be gauged from the fact that in 1957 alone, contracts for new equipment to a total value of more than £40,000,000 had been placed.

Minor Losses in Metering Nozzles

By T. H. REDDING, M.Sc., F.Inst.P., A.M.I.Mech.E.*

No. I

An extended one-dimensional study of converging flow in closed channels leads to a general equation for the pressure drop versus (bulk) flow-rate relationship. This is sufficiently comprehensive to indicate the trends of variation of the value of the flow coefficient with respect to many possible variations in the flow conditions (both upstream of and within the convergence itself) which are not ordinarily taken into account in more elementary treatments of the subject. Following a comparative study of the geometry and flow-characteristics of two series of parallel-throated nozzles used for metering (A.S.M.E. and I.S.O. metering nozzles) the above equation is used to evaluate and discuss probable values for the minor energy-loss factors (or so-called "minor losses"), which define the extent to which irreversible work is done by the fluid in the course of its passage through the nozzle. These evaluations reveal systematic but opposite tendencies in the manner in which the respective (A.S.M.E. and I.S.O.) minor losses vary with the throttle (area) reduction-ratio, and are shown to be such as to substantiate known (or probable) characteristic features of the flow patterns, as have been determined (or inferred) from other experimental and theoretical studies in this field.

EXPERIMENTAL investigations on the flow of fluids through pipe-convergences have been stimulated by three major interests, viz. the production of high jet velocities (in the construction of turbines and jet propulsion devices), rate of flow regulating devices (valves) and the inferential measurement of rate of fluid flow from observations of the pressure drop across the convergence. The subject, not being amenable to direct theoretical treatment, has resulted in experimental data being correlated on an empirical rather than a rational basis, with a primary view to establishing techniques for scaling the results of given experiments to apply to larger or smaller devices of the same kind. Generally, this method of approach has proved adequate in dealing with many—if not most—of the essentially engineering (i.e. constructional) problems which have arisen in this field. However, it is only in comparatively recent years that systematic attempts have been made to study such phenomena from the point of view of rational theories of fluid mechanics in various endeavours to attach physical significance to (experimentally determined) flow coefficients, as arise in course of so-called one-dimensional (i.e. energy-transfer) treatments of the subject. Such studies have shown the flow coefficient to be a function of other more fundamental quantities which are directly related to the flow pattern. Furthermore, in some cases, the values of some or all of these factors can be evaluated theoretically from rational formulæ based on the principles of fluid mechanics. In most cases, however, our present state of knowledge permits only partial theoretical solutions to problems of this kind, the possible degree of completeness of a solution depending on the complexity of the geometry of the convergence and its approach channel and on the physical conditions under which flow takes place.

In this connection, precise experimental data on flow through channel-convergences is of obvious value, since each correlation of the pertinent variables—expressed systematically in terms of non-dimensional quantities—provides the means of indirect confirmation (or otherwise) of the assumptions and principles on which theoretical treatments are founded. However, it is of utmost importance to know the order of the probable error in the results of any experiments used for such analytical purposes, since, in most cases, the constitution of the experimentally determined flow coefficient is such as to make it a relatively insensitive measure of the more fundamental quantities of which it is composed. Consequently, it is conceivable that quite unjustified criticism could be levelled at a proffered theoretical treatment as a result of analysing insufficiently accurate experimental data—although such data might be well within the limits of accuracy required for engineering design purposes. Thus, for example, in (non-contracted) nozzle flow at an area-reduction ratio of 0·5, an error of 2·5 per cent in determining the flow coefficient gives rise to a quite impossible—i.e. negative—value for the computed (inferred) value of the energy loss factor—one of the basic quantities entering in the theoretical expression for the flow coefficient itself. This conception—i.e. that under certain circumstances considerable physical changes in the flow pattern are but weakly represented by their effect on the flow coefficient—is by no means self-evident. The matter is, however, most aptly noted by Bean, Reynolds and Johnson[1] in discussing the difficulties attending the accurate evaluation of the third significant figure of the flow coefficient of metering nozzles due to peculiarities of the flow rather than to errors of observation.

It is, perhaps, only in the field of flow through constrictions used for metering purposes (i.e. orifices, nozzles and venturi tubes) that available experimental data is sufficiently accurate to justify its being used to substantiate theoretical treatments; and/or, when circumstances permit, to compute probable values of one or other of the basic parameters which go to constitute the flow coefficient or other (experimentally determined) flow characteristics of the system in question. However, even in these cases, very careful discrimination is necessary before accepting experimental results for analytical purposes. In fact, in the author's opinion, much of the existing data on metering devices needs to be revised and supplemented by precise determinations of the flow coefficient under conditions other than those normally associated with metering practice, if detailed information is to be established on the constitution of the flow coefficient and on the precise mechanism of converging flow. Thus, for example, precision experiments with metering throttles in very rough pipes at both high and low Reynolds numbers and/or with variously produced (but known) upstream velocity profiles would, by their very nature, exaggerate the effect of one or more of the fundamental parameters and so facilitate the measurement problems required to investigate the effect of these quantities on the flow coefficient—or for that matter on any other pertinent data relating to the flow pattern (e.g. axial and wall values of the pressure gradient). On the other hand, experiments with less pronounced (i.e. near-normal) values of the condition parameters could conceivably lead to quite inconclusive results in so far as the effect—or even the trend of effect—of these quantities on the flow coefficient is concerned.

* British Scientific Instrument Research Association

Minor Energy Loss Factor E*

The derivation of the minor energy loss factor E in a channel convergence, from measured values of the flow coefficient, is a case in point of the arguments set out above. Sometimes known as the minor loss factor, E, in the case of well-rounded convergences, is seldom large enough to be of any importance from a purely engineering point of view: however, in theoretical studies it appears as one of the factors which contribute towards the value of the flow coefficient and whose physical significance, in some cases, can be interpreted in terms of possible—if not certain—characteristic trends in the pattern of the flow. In what follows this (basic) parameter will be considered with particular reference to its function in flow through two well-known parallel-throated nozzles—viz. A.S.M.E. and I.S.O.† metering nozzles.

However, the relevant (constitutional) formula for the flow coefficient, on which these evaluations of E are based, will be derived as a particular instance of a general equation relating to converging flow. This method of approach has the advantage of being useful for reference when discussing, more generally, the theoretical implications of experimental work on converging flow. In addition, it is of interest in bringing to light the large number of basic parameters associated with the general case and also the manner in which these quantities contribute to the value of the flow coefficient.

A.S.M.E. and I.S.O. Nozzle Forms

A.S.M.E. High-Ratio (H.R.) and Low-Ratio (L.R.) Metering Nozzles.—These are forms of long radius elliptical metering nozzles, the first detailed specification of which appeared in 1937[2] and which were subsequently accepted by the A.S.M.E. as standard metering devices.[3]

The High-Ratio Nozzle is illustrated in Fig. 1(*a*), where its axial cross section is shown

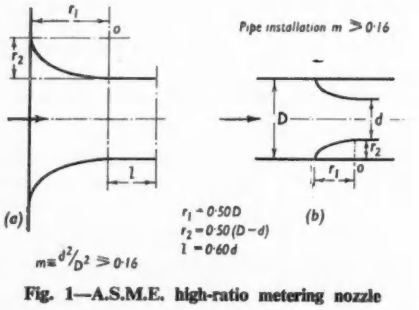


Fig. 1—A.S.M.E. high-ratio metering nozzle

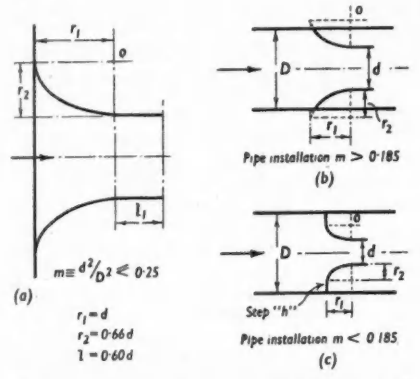
as a quadrant of an ellipse having semi-major and semi-minor axis of length $0{\cdot}5D$ and $0{\cdot}5(D-d)$ respectively, followed by a short cylindrical exit piece of length $0{\cdot}6d$. Thus the eccentricity of the entrance section and the ratio of the length of the exit piece to the pipe diameter are dependent on the area reduction ratio m, where $m=(d/D)^2$, both

* E is here defined conventionally by the relation $Z=E\frac{V^2}{2}$ where Z is the total irreversible work done per unit mass of fluid passing through (but not beyond) the convergence, and V the mean fluid velocity in the reference section (usually taken at the throat). Defined in this way, E does not include the energy loss in the divergent efflux which occurs after the fluid leaves the throat of the nozzle.

† A.S.M.E.=American Society of Mechanical Engineers. I.S.O.=International Organization for Standardization.

these quantities increasing with increasing values of m. Furthermore, the axial cross section of the entrance piece remains a complete quadrant of an ellipse irrespective of the value of m, since the diameter of the largest (i.e. entry) transverse section of the entrance piece D_0 is, in all cases, the same as the diameter of the pipe itself—see Fig. 1(*b*). The nozzle is recommended for use in all cases where $m>0{\cdot}16$.

The Low-Ratio Nozzle is illustrated in Fig. 2(*a*), where the axial cross section now takes the form of part or whole of a quadrant of an ellipse having semi-major and semi-minor axis of length d and $0{\cdot}66d$ respectively, followed by a cylindrical exit piece of length $0{\cdot}6d$. In this case the eccentricity of the entrance section, being fixed at a value 0·745, is independent of the reduction ratio, but, as in the case of the high-ratio nozzle, the length of the exit piece (reckoned in terms of the pipe diameter) increases with increasing values of m. In this case, however, the axial section of the entrance piece only takes the form of a complete quadrant of an ellipse (and nothing more) for one value of the reduction ratio, i.e. $m=0{\cdot}185$—corresponding to the largest transverse section of the entrance piece coinciding with the pipe diameter. For area reduction ratios greater than 0·185 the axial section of the entrance piece is a segment only of this ellipse—viz. that within the pipe section, as shown in Fig. 2(*b*)—whilst for area reduction



$C_p \equiv$ discharge coefficient relevant to pipe-wall (D, $0{\cdot}5D$) pressure taps, after Bean, Beitler and Sprenkle (see reference 4).

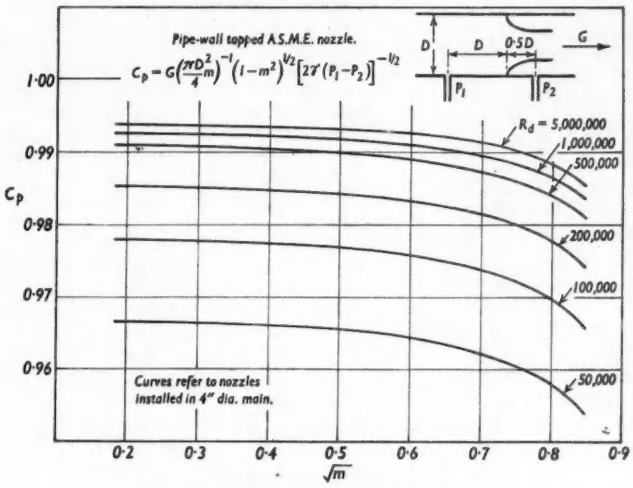
Fig. 2—A.S.M.E. low-ratio metering nozzle

ratios less than this value a perpendicular from the pipe wall joins with the (horizontal) vertex of a fully developed elliptic quadrant to form a "stepped" or "dammed" entrance, as shown in Fig. 2(*c*). The nozzle is recommended for use in all cases where $m<0{\cdot}25$.

The calibration of the nozzles, with variously positioned pressure tappings and under various conditions of installation, with both incompressible and compressible fluids, has formed the subject of many researches. However, the basis of the present analysis is a paper by H. S. Bean, S. R. Beitler and R. E. Sprenkle,[4] in which the discharge coefficient‡ C is established (for incompressible flow) as a function of the diameter reduction ratio d/D for various selected values of the Reynolds number and the pipe diameter, when the working differential pressure is measured between so-called "pipe-wall" pressure taps situated $1D$ upstream and $0{\cdot}5D$ downstream of the plane of the nozzle inlet. For reference purposes the calibration curves relating to a 4in diameter pipe, as established by the above authorities, is reproduced in Fig. 3.

‡ In this article the term "discharge coefficient" will be used to designate the quantity $C=G(F_2m)^{-1}(1-m^4)^{1/2}[2\gamma(P_1-P_2)]^{-1/2}$, whilst the term "flow coefficient" will refer to the quantity $\alpha=G(F_2m)^{-1}[2\gamma(P_1-P_2)]^{-1/2}$—where G is the mass rate of flow, F_2 the sectional area of the main, m the area reduction ratio of the nozzle, P_1 and P_2 the pressures at upstream and downstream pressure taps, and γ the fluid density. The two coefficients are therefore connected by the simple relation $C=(1-m^4)^{1/2}\alpha$. In elementary texts, C is often defined as the ratio of the actual to the "theoretical" rates of flow; the theoretical flow rate being derived as the quantity $(F_2m)(1-m^4)^{-1/2}[2\gamma(P_1-P_2)]^{1/2}$.

For analytical purposes, the flow coefficient will be used throughout, the term "discharge coefficient" being reserved for occasions when it is required to refer to the original presentation of the results of experiments wherein this coefficient is used as the working parameter.



$(P_1)_M$ = minimum (wall) pressure upstream of nozzle.
$(P_2)_M$ = minimum (wall) pressure downstream of nozzle.
P_1 = wall pressure at distance a_1 upstream of nozzle.
P_2 = wall pressure at distance a_2 downstream of nozzle.
$(\Delta P)_1 = P_1 - (P_1)_M : (\Delta P)_2 = P_2 - (P_2)_M : (\Delta P)_M = (P_1)_M - (P_2)_M$
$\frac{(\Delta P)_1}{(\Delta P)_M}$ versus a_1/D and $\frac{(\Delta P)_2}{(\Delta P)_M}$ versus a_2/D, after Bean and Beitler (see reference 5).

Fig. 3—A.S.M.E. nozzles: characteristics C_p versus $\sqrt{m}$ at constant R_d

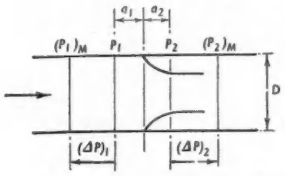
As the present analysis requires the use of flow coefficients other than those appertaining to "pipe-wall" pressure tapping positions, reference has been made to a further paper[5] which gives information on the pressure gradients upstream and downstream of A.S.M.E. flow nozzles: this permits the calculation of the flow coefficient with respect to arbitrarily chosen pressure taps when the position of these is specified in relation to a standard position (e.g. that of pipe-wall taps), for which the flow coefficient has already been determined. For reference purposes these gradients—as given by Bean and Beitler for a 4in diameter main—are reproduced in Fig. 4. In this diagram (wall) pressure drop upstream and downstream of the nozzle is represented by the ratios $(\Delta P)_1/(\Delta P)_M$ and $(\Delta P)_2/(\Delta P)_M$ respectively, where $(\Delta P)_1$ (and $(\Delta P)_2$) are the pressure differences between the given upstream (or downstream) pressure taps and those points upstream (or downstream) of the nozzle at which the pressure gradient vanishes, and $(\Delta P)_M$ the pressure drop between these zero-pressure-gradient tapping positions themselves. From the curves it is apparent that the fraction $(\Delta P)_1/(\Delta P)_M$ increases as the nozzle is approached from the upstream side, and that over the range of nozzles tested, the effect increases with increasing values of the area reduction ratio. On the other hand, downstream of the nozzle, there is a tendency towards a stationary value for the fraction $(\Delta P)_2/(\Delta P)_M$ between the downstream stations $a_2/D=0{\cdot}4$ and $a_2/D=0{\cdot}6$.

I.S.O. Metering Nozzle.—This (short radius) metering nozzle, previously known as the I.S.A.§ (1932) standard nozzle, was first proposed as an international standard metering device in 1932.‖ In all its essential features the nozzle is identical with the V.D.I.¶ standard metering nozzle—first

§ I.S.A. = International Federation of the National Standardizing Associations—an organisation which preceded the present International Organisation for Standardization (I.S.O.).

‖ This proposal was made at the 1932 (Milan) meeting of the I.S.A., but publication of the relevant specification (as I.S.A. *Bulletins* 9 and 12)[6, 7] was delayed till 1935–36.

¶ *V.D.I.* = *Verein Deutscher Ingenieure.*



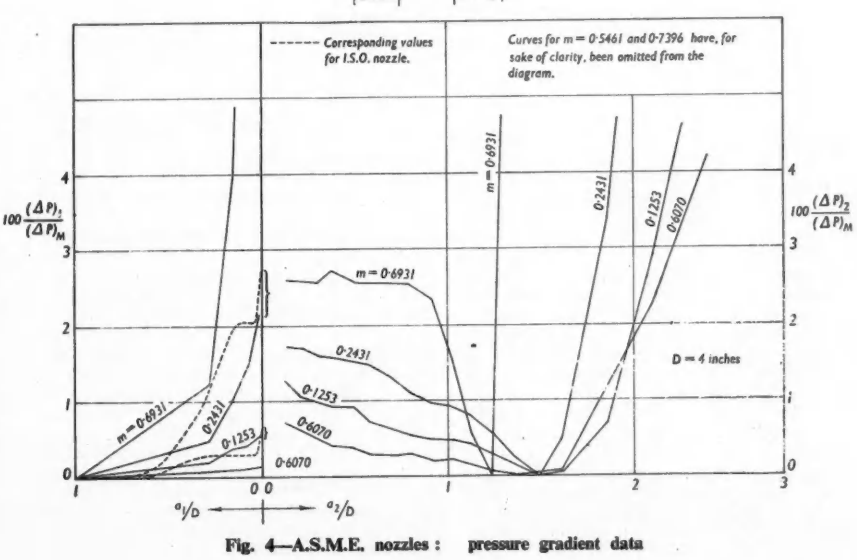
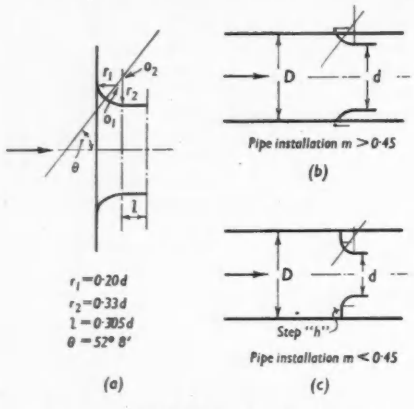


Fig. 4—A.S.M.E. nozzles: pressure gradient data

specified as a (German) national standard in 1930[8]—and which, in turn, is based on a nozzle form described by Witte[9] known (previous to 1930) as the "I.G."** nozzle form. Characteristic of the nozzle is the sharp curvature of the entrance piece and the short length of the cylindrical exit piece, both of which dimensions are probably very near the limiting values necessary to ensure contraction-free flow in the cylindrical throat.

The nozzle form is illustrated in Fig. 5(*a*),

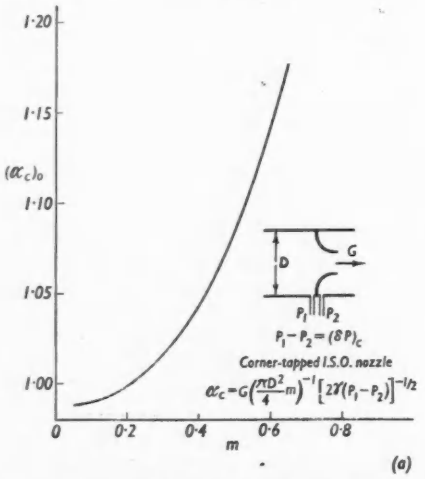


$\alpha_e = f_R \cdot f_D \cdot (\alpha_c)_o$, after D.I.N., 1952 (see reference 8).
where: $(\alpha_c)_o$ ≡ flow coefficient of corner-tapped nozzles installed in mains of diameter greater than 8in, at Reynolds numbers in excess of $R_d = 100{,}000$.
α_c ≡ corner-tapped flow coefficient for $D < 8$in and $R_d < 100{,}000$.

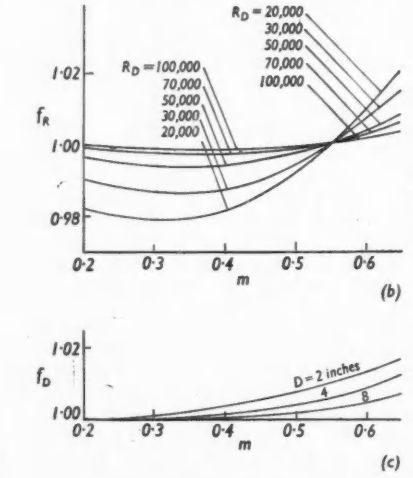
Fig. 5—I.S.O. metering nozzle

where its axial cross section is shown as a quadrant of an oval (having leading and following radii of $0{\cdot}2d$ and $0{\cdot}33d$ respectively centred on a line inclined at 52 deg. 8 min. to the pipe axis) followed by a cylindrical exit piece of length $0{\cdot}305d$. The form of the axial sections of the entrance piece is very nearly identical with an ellipse having major (axial) and minor (transverse) semi-axis of $0{\cdot}304d$ and $0{\cdot}25d$ respectively; thus, as with the A.S.M.E. low radius nozzle, the eccentricity of the entrance section is fixed (at 0·569) and independent of the area reduction ratio, whilst the length of the exit piece (reckoned in terms of the pipe diameter) increases with increasing values of the reduction ratio. Again, the axial section of the entrance piece only takes the form of a complete oval (and nothing more) for one value of the area reduction ratio, viz. for $m = 0{\cdot}45$—corresponding to the largest transverse section of the entrance piece coinciding with the pipe diameter. For area reduction ratios greater than 0·45 the axial section of the entrance piece is a segment only of the specified oval, viz. that part within the pipe section—as shown in Fig. 5(*b*)—whilst for area reduction ratios less than 0·45 a perpendicular from the pipe wall joins with the (horizontal) vertex of a fully developed oval-quadrant to form a stepped or dammed entrance, as shown in Fig. 5(*c*).

** I.G. = I.G. Farbenindustrie.



$(P_1)_c$ = (corner) pressure immediately upstream of nozzle.
$(P_2)_c$ = (corner) pressure immediately downstream of nozzle.
P_1 = wall pressure distance a_1 upstream of nozzle.
P_2 = wall pressure distance a_2 downstream of nozzle.
$(\delta P)_1 = (P_1)_c - P_1$: $(\delta P)_2 = (P_2)_c - P_2$: $(\delta P)_c = (P_1)_c - (P_2)_c$.



$\frac{\delta P_1}{(\delta P)_c}$ versus a_1/D and $\frac{\delta P_2}{(\delta P)_c}$ versus a_2/D, after Witte (see reference 12).
(D = 8in, δ = tapping hole diameter = $0{\cdot}01D$).

Fig. 6—I.S.O. nozzles: characteristics α_c versus m

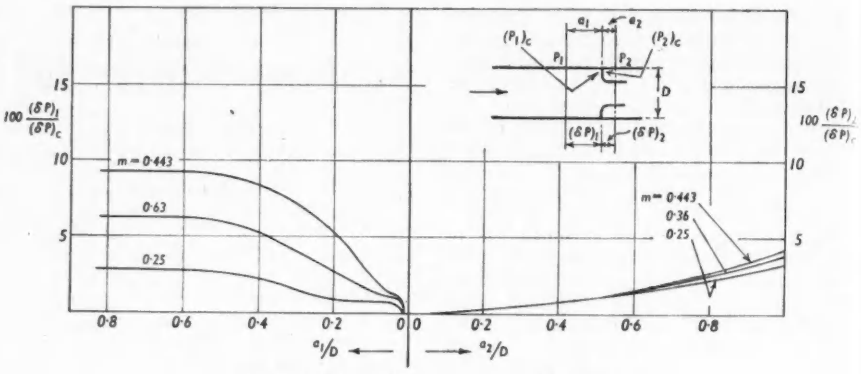


Fig. 7—I.S.O. nozzles: pressure gradient data

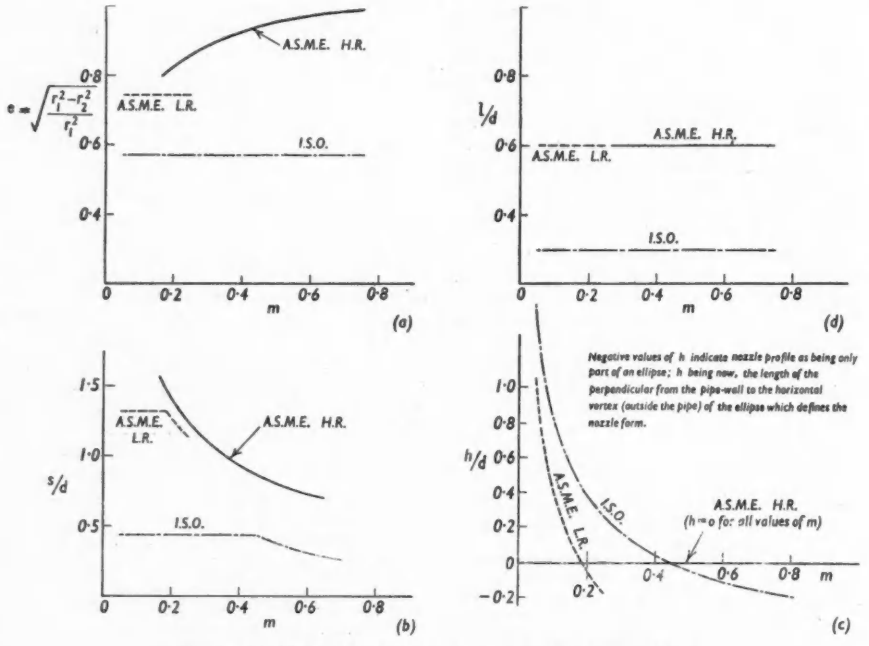

A.S.M.E. H.R.
A.S.M.E. L.R.
I.S.O.
$e = \sqrt{\frac{r_1^2 - r_2^2}{r_1^2}}$
m
(a)
l/d
(d)
s/d
(b)
h/d
Negative values of h indicate nozzle profile as being only part of an ellipse; h being now, the length of the perpendicular from the pipe-wall to the horizontal vertex (outside the pipe) of the ellipse which defines the nozzle form.
A.S.M.E. H.R. (h = o for: all values of m)
(c)

Fig. 8—A.S.M.E. and I.S.O. nozzles: geometrical comparisons

The calibration of the nozzle, under various conditions of installation with both incompressible and compressible fluids, has formed the subject of many researches—notably those of Witte[9, 10, 11, 12, 13, 14] and his co-workers. However, coefficient data, when required in the following analysis will be taken from the sixth (1948) edition of *D.I.N.*, 1952 (*Regeln für die Durchflussmessung mit genormten Düsen und Blenden*),[8] which specifies the most acceptable values for the flow coefficient as a result of a correlation study of available reports of experimental work in this field. Data given in this publication, particularly in so far as flow at $R_D < 100{,}000$ is concerned, is more complete and reliable than that given in the original (1935–36) I.S.A. specification. For reference the relevant calibration curves, as established by the above authority, are given in Figs. 6(*a*), 6(*b*) and 6(*c*). This representation comprises a basic curve "flow-coefficient α versus m" (Fig. 6(*a*)) [which applies specifically to mains of diameter greater than 8in and Reynolds number (calculated with respect to the pipe diameter) greater than 100,000], together with supplementary curves of multiplying factors (or so-called correction factors), which take into account the effect of pipe diameter (when $D < 8$in) and the Reynolds number of the flow (when $R_D < 100{,}000$).

Again, in the absence of flow coefficient

data other than that appertaining to corner taps, it will be necessary to use the corner-tap coefficient, in conjunction with upstream and downstream pressure gradient data, in order to compute values of the flow coefficient for non-standard (i.e. other than corner) tapping positions. This information (on the pressure gradient) has been determined by Witte,[12] whose data—relating to an 8in diameter pipe and tapping-hole diameter $\delta=0{\cdot}01\ D$—is reproduced, for reference, in Fig. 7. These experiments indicate that the apparent (wall) pressure gradient—as determined by observation of manometers connected to tapping holes of finite diameter—is dependent on the diameter δ of the tapping holes themselves ; but this is not surprising in view of the steep pressure gradient immediately upstream of the nozzle entrance. However, Witte's determination of the pressure gradient —as measured with the smallest of the tapping holes used in these experiments, i.e. with $\delta=0{\cdot}01D$, probably gives a tolerably exact picture of the true pressure gradient in the vicinity of the nozzle. Consequently, in what follows we shall use the pressure gradient curves relevant to $\delta=0{\cdot}01D$, in conjunction with standard values of the corner-tap coefficient, to evaluate the most probable value of the flow coefficient relevant to pipe-wall (or other) positions of the pressure tappings. Adopting this procedure is tantamount to assuming that the standard values of the corner-tap flow coefficient most nearly approach their quoted values—i.e. are subject to minimum probable error—when the diameter of the corner pressure tapping holes themselves is set at $\delta=0{\cdot}01D$. However, the standard specification (*D.I.N.*, 1952) does not go so far as this, but merely states that quoted values of the flow coefficient applicable to corner taps are subject to a probable error of not more than ±1 per cent, providing the diameters of the pressure tapping holes are less than $0{\cdot}03D$.

The above remarks on the effect of pressure tapping-hole diameter apply equally to the measurement of the pressure gradient in the vicinity of A.S.M.E. nozzles. However, as the purpose of referring to this data is to calculate a value for the flow coefficient for pressure taps $1D$ and xD upstream and downstream of the nozzle inlet (being given the value of the coefficient appropriate to pipe-wall pressure tappings), it will only be necessary to refer to the downstream pressure gradient curve—since, with pipe-wall (D, $0{\cdot}5D$) taps, the upstream tapping already occupies the $1D$—position. In this (downstream) region, except at high values of the area reduction ratio, $(\Delta P)_2/(\Delta P)_M$ and the rate of change of this quantity along the pipe wall are essentially small, so that lack of precise information on the variation of $(\Delta P)_2/(\Delta P)_M$ with respect to δ/D is relatively unimportant.

The parameters used by Witte in presenting the results of these experiments differ somewhat from those used by Bean and Beitler for the case of A.S.M.E. nozzles, in that the working parameters $(\delta P)_1/(\delta P)_c$ [and $(\delta P)_2/(\delta P)_c$]—as shown in Fig. 7—refer to the ratio of the pressure drop between the upstream (or downstream) corner tap and the given upstream (or downstream) tapping position to that of the pressure drop $(\delta P)_c$ between the upstream and downstream corner taps themselves [cf. Bean and Beitler, who, favouring the parameters $(\Delta P)_1/(\Delta P)_M$ and $(\Delta P)_2/(\Delta P)_M$, measure upstream and downstream pressure drops with respect to datum positions coincident with the positions of minimum pressure occurring upstream and downstream of the nozzle respectively].

However, on expressing Witte's results in terms of the parameters $(\Delta P)_1/(\Delta P)_M$ and $(\Delta P)_2/(\Delta P)_M$ and cross plotting to obtain values of these variables appropriate to the area-reduction ratios used by Bean and Beitler, the results of the two series of experiments appear to be very similar, in spite of the substantial differences in the entrance conditions (i.e. entrance curvature and dam height) which prevail (see broken curves on Fig. 4). The very nearly stationary value of the pressure gradient, which is apparent in Witte's original curves for the upstream pressure gradient in the near vicinity of the nozzle, is carried over to the new representation ; but the fact that similar " steps " are not apparent in the curves due to Bean and Beitler (even if not quite so pronounced in view of the comparatively modest curvature of the A.S.M.E. nozzle entrance piece) might well be due to the effect having been overlooked by virtue of their having used a smaller (4in diameter) pipe, with consequent limitations on the possible number of pressure tappings in the immediate upstream vicinity of the nozzle.

As will be apparent from the above description, there are marked differences between the A.S.M.E. and I.S.O. nozzle forms, both in their basic geometry and in the manner in which certain dimensions are subject to variation according to the value of the area reduction ratio used. Conveniently, the relevant comparative geometrical data can be expressed in graphical form as in Figs. 8(*a*) to 8(*d*), which show e, s/d, h/d and l/d as functions of the area reduction ratio m—where e and s are the eccentricity and curved length of the (axial) section of the entrance piece respectively, h the height of the dam (or step) leading to the entrance section proper, and l the length of the cylindrical exit piece.

(*To be continued*)

The Radio Telescope at Jodrell Bank

A radio telescope, which can be steered to any point in the sky, is nearing completion at Manchester University's experimental station in Cheshire. The telescope has a paraboloidal reflector, 250ft in diameter. It can pick up wavelengths as short as 20cm. This article concentrates principally on an outline of the engineering problems involved, such as the need for very slow movement to " track " a star successfully, and the need for maximum deflections of only about 1in from the true shape of the paraboloid, under working conditions with winds up to 30 or 40 m.p.h.

LAST week, the Department of Scientific and Industrial Research organised a series of press visits to the large radio telescope now nearly completed at the Jodrell Bank experimental station in Cheshire. This enormous instrument is of special interest, not only because of its uniqueness and promise for the astronomer, but also because of the engineering problems which had to be surmounted to design and build it. Civil, mechanical and electrical engineering techniques are all involved in the successful operation of the radio telescope, sometimes in an original manner. In this article we concentrate on describing, in outline, these various engineering problems, but before doing so the telescope itself and the way in which it will function is explained, and we give a short dissertation on radio astronomy.

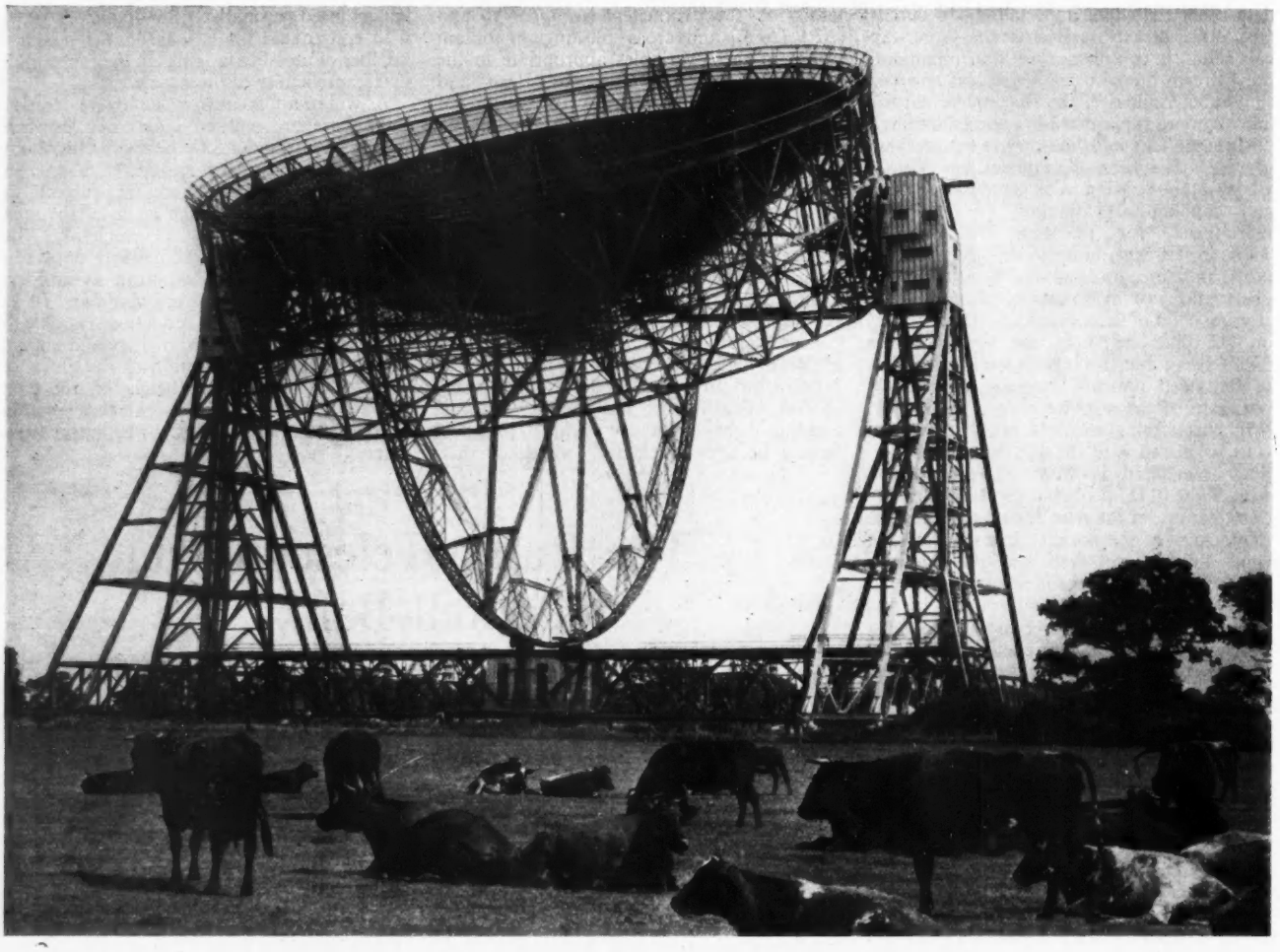
The main aim was to produce a fully steerable paraboloid reflector of the largest size practically possible. The bowl is in fact 250ft in diameter and is carried on two towers by trunnion bearings ; it can be turned on these bearings through 180 deg. The towers are mounted on bogies on a circular rail track so that the whole structure can be rotated. Driving and control mechanisms are installed in such a manner that the telescope can be pointed at any given star and can be driven to follow the path of the chosen star till it disappears below the horizon. The telescope is thus analogous to an optical telescope, but it will pick up radiations of much longer wavelengths. It can also be used to transmit, in the manner of radar equipment, and pick up reflected waves from comparatively close objects. Originally the standard of accuracy aimed at was sufficient to work with radio waves down to about 1m wavelength, but the design was changed, and the aim now is to study shorter wavelengths as well, down to about 20cm.

The justification for the steerable instrument at Jodrell Bank arose from the important results obtained from a " fixed " reflector 218ft in diameter in the form of a paraboloid facing upwards constructed of thin wires stretched on tubular scaffolding, erected in a field at the Jodrell Bank Research Station. In fact, this so-called " fixed " reflector, by virtue of the earth's rotation, was constantly observing a "slice" of space. The " thickness " of this slice could be increased within small limits by displacing the receiving aerial on either side of the true focus of the paraboloid on a tilting aluminium alloy mast 120ft high, which was capable of remote control. An early conception for a more useful radio telescope of very large dimensions was to mount the reflector on a tilting platform so that with the aid of the earth's rotation a much wider band of space could be observed. Whilst such a solution greatly simplified the engineering problems, the field of such a telescope was severely limited because it was still dependent on the rotation of the earth and could not be kept fixed on any point under observation, nor could it be used to track moving objects in space.

Principal Dimensions of the Radio Telescope

Diameter of paraboloidal bowl	250ft
Height of aerial mast	62½ft
Weight of bowl	750 tons
Total weight of moving parts	2000 tons
Radii of circular tracks :	
Inner track	159ft 6¾in
Outer track	176ft 4-7/16in
Height to axis of trunnions	165ft
Height to top of towers	185ft
Height to top of bowl (in horizontal position)	215ft
Maximum height with bowl tipped	300ft
Depth of bowl structure :	
At circumference	73ft 4½in
At centre	10ft 9in
Bowl trunnions :	
Length	8ft 9in
Diameter	3ft
Maximum speeds of movement of telescope :	
In azimuth	20 deg. per minute
In elevation	24 deg. per minute

The four major problems with which the consulting engineers were faced were thus (1) to design a reflector 250ft in diameter which would keep its shape within close limits during rotation and under the effects of considerable wind pressures and temperature variations ; (2) to provide a driving system sufficiently powerful to control the telescope under any foreseeable wind conditions ; (3) to produce a method of control of the driving system so that the telescope would automatically follow any point in space irrespective of the rotation of the earth and the movement of the earth round the sun, together with facilities for scanning predetermined areas in space and tracking moving objects ; (4) to produce a design which could be carried out by constructional firms and machinery manufacturers, none of whom could have had previous experience of building a mobile apparatus of such magnitude.



The radio telescope is here seen almost completed, with the construction of the steel plates forming the reflecting surface well advanced. Radio beams are reflected on to an aerial, mounted on a steel tower, at the focus of the 250ft paraboloid

Radio Astronomy

In spite of its fascination, the science which this instrument will further cannot be mentioned here except in the briefest manner. However, we would refer readers to THE ENGINEER of May 9, 1952, page 640, when an article on radio astronomy was published at the time that the Jodrell Bank project was announced. Even since that time, radio astronomy has made some important progress, and we understand that all of this progress has underlined the value of the decision made at that time to build such a large and expensive instrument. The subject is essentially post-war, and depends to a large extent on radar techniques, which were largely developed because of the war.

Apart from radiations in the visible wavelengths, waves between limits of about a few centimetres (this lower limit being due to atmospheric absorption) and about 20m (this upper limit being due to reflection from the Heaviside layer) penetrate to the earth's surface. Signals picked up in this band—the so-called "radio stars"—cannot yet be fully explained but their study is expected to yield fundamental knowledge about the composition and structure of the universe. The distribution of energy in a hot body such as a star is well known, but fails to account for the radio signals picked up by instruments such as the telescope described here. The view has been put forward that these radio signals are generated by clouds of very rarified hydrogen gas present in interstellar space ; the 21cm spectral line radiated by hydrogen under certain conditions has thus been an important subject of study. It is now widely accepted that radio sources are widely dispersed throughout the extra-galactic star systems of the universe.

Performance of the Telescope

Because of the intensity of the radio sources identified in the extra-galactic systems, it is considered that the Jodrell Bank telescope will penetrate as far as 10^9 light years, an order of distance far greater than the range of the largest optical telescopes, and very possibly, about as far as astronomers will succeed in penetrating. Surveys of radio sources carried to this extent will give experimental confirmation of hypotheses about the structure of the universe. Amongst its initial research programmes, the telescope will also be used to study the physics of meteors, and the aurora borealis, and it is hoped to transmit a signal and reflect it back, from the planet Venus.

It is pointed out that the telescope, because of its great size, will be the most sensitive short-wave radio receiver yet constructed, and also the most far-reaching transmitter. Its beam width when used on a wavelength of 1m will be about 1 deg., and its power gain will be over 16,000. On the 21cm hydrogen spectral line wavelength, its beam width will be only a few minutes of arc.

The required position of the telescope at any instant, when it is following a star's track, is continuously calculated by a computer. The actual position is measured, and the difference fed into the control system. The required position is calculated to 4 minutes of arc, and the actual position of the telescope is known to about 1 minute of arc. The overall accuracy with which the instrument can be aimed and used is about 12 minutes of arc.

The instrument is complementary to another class of instruments used for this work—the interferometers. A large interferometer is at present nearing completion at Cambridge. An even greater size of bowl than that actually built at Jodrell Bank, would, of course, give greater accuracy. We understand, however, that future improvements in such instruments are likely to lie in better electrical techniques—especially amplification—and in higher precision generally, as much as in attaining greater size.

Structural Design

From the outset the consultants decided to build the telescope entirely of steel. Aluminium alloy was suggested as an alternative, but the opinion was held that the arguments in favour of steel were irrefutable, viz. the highest strength/cost ratio ; a low coefficient of expansion, so that reasonable accuracy of shape could be maintained without complicated temperature compensating devices ; a higher modulus of elasticity than light alloy, which reduces deflections as load distribution changes due to rotation of the bow; and a greater weight, which, it was considered, added stability against the overturning effects of wind and against gusts. Mild steel was the choice for these conditions, and not high-tensile steel.

The structural design then rested on three principal requirements. First, stability, in which wind forces were the critical factor ; secondly, stiffness sufficient to keep the bowl truly to shape within the limits specified ; and thirdly, to maintain these limits so as to allow operation in moderate winds, up to, say, 30 or 40 m.p.h. It became evident that generally stiffness was the critical factor amongst these three, and the requirement for deflections has governed the design to a considerable extent. The original requirement for using the telescope with wavelengths down to about 1m, allowed deflections of several inches—say, 6in or 7in. At that time the bowl structure was designed as a large bowed beam spanning between the trunnions, with cantilevers at right angles to it. But as it is now built, any deviation of the skin of the paraboloid from its true shape is intended to be kept down to about 1in.

The general form of the structure carrying the bowl can be seen in the illustrations. Around the periphery of the bowl is a very deep ring beam, composed of sixteen panels. These panels are braced in the form of a diamond, rather like the

bracing of a Bailey bridge panel, but the relative slenderness of the individual members of the panel is striking in the radio telescope, indicating the importance of stiffness. Two of these panels are, however, more stoutly built to carry the trunnion assemblies. A heavily-built ring fits inside the diamond bracing of these two panels, and is riveted to the cone of steel sheet which, in its turn, is attached to the trunnion bearing.

From each of the vertical members of these outer panels deep K-braced trusses extend radially under the bowl, to a central "spider" or ring structure, rather similar in general form to the outer one. As can be seen from the table, there is still an appreciable structural depth under the spider.

This system, comprising essentially an inner and an outer ring girder, with radial trusses connecting them, was designed as a space frame. Secondary and tertiary bracings complete the frame. The bowl itself consists of stiffened steel plates welded to purlins. The purlins are bolted to the main structure, so it is possible to align the shape of the bowl by adjusting these bolted connections. One other adjustment is possible through the circular gust-resisting girder at the centre, whose function is explained below. Neither this girder nor the steel sheeting of the bowl were taken into account in assessing structural stiffness, though they do make some contribution.

The two towers which carry the trunnion bearings are connected together at the base by a braced box-beam structure of great rigidity. This beam spans the inner rail diameter of approximately 320ft and is 40ft wide by 20ft deep. At its centre (i.e. at the centre of rotation of the whole instrument) there is a pivot, set into a concrete anchorage, which holds the telescope centrally on its rail track. Note the "outrigger" bracing on each side of each tower; similar horizontal bracing extends from the central beam to the feet of the towers. Each tower rests on six bogies. There are two powered driving bogies under the central part of the tower which normally carry the greater part of the deadweight, and two "outrigger" idler bogies on each side of these central ones under the inclined legs of the tower, and these bogies function principally to resist overturning moments due to the wind.

Wind tunnel tests were, of course, an important part of the structural design, and a model of 1/100th scale was tested in a wind tunnel at the National Physical Laboratory. The worst condition was found to be with the bowl of the telescope at 45 deg., and an overturning force of 700 to 800 tons was evaluated, corresponding to a wind speed of 100 m.p.h. Flutter and instability were not serious at wind speeds less than about 150 m.p.h., but one problem remained, namely, to stabilise the bowl against gusts which would not be structurally dangerous, but would adversely affect the telescope's operation. For this reason the circular beam extending downwards from the centre of the bowl structure, and braced to it, was included in the design. This beam bears against the rubber-tyred wheels of two bogies which can be seen in the illustration projecting above the roof of the motor room. The wheels can be pressed upwards against the lower flanges of this curved beam by jacks which can exert a force of up to 80 tons. The wheels are those normally used for heavy commercial vehicles, and they can be braked, in the usual manner. So, by applying the brakes, the bowl can be damped. The 80-ton jacking force can also be applied, if necessary, to adjust the shape of the paraboloid, as mentioned above.

The bowl of the telescope can be completely inverted and will, in fact, be placed in such an attitude when the aerial has to be changed. It will be appreciated that load reversal then occurs in some members of the bowl structure, but presumably the stringent deformation limit for operation is not critical in this situation. The support of the bowl on two trunnions is, of course, most unusual for a structure of such size, and provides unusually favourable conditions for measuring loads and deflections imposed on it, and hence checking the theoretical work, both for the structural computations and the wind tunnel analyses. Such tests are, in fact, being carried out and strain gauges have been fitted to the structure.

Erection

Comparatively soft upper beds of clay and sand are underlain by a stratum of hard marl at the radio telescope's site. Bored piles have been taken down to the marl to carry the instrument. This bearing stratum is very irregular and the toes of the piles vary from 37ft to 90ft below ground level. Each pile is 19in in diameter and was designed for a maximum load of 76 tons. Six piles carry the central thrust block and 146 carry the ring beams. The central block is of concrete 10ft deep and 24ft in diameter, with an annular access passage left in it leading to the cable tunnel between the control building and the telescope. The reinforced concrete ring beams are each 6ft wide by 3ft deep and are joined by an 8in slab. Each rail track consists of twin 109 lb flat-bottomed rails laid on mild steel base plates to a tolerance of $\frac{1}{16}$in in line and level; the outer track is approximately 350ft in diameter.

Erection of the structural steelwork was based on the use of two 15-ton Scotch derricks mounted on 120ft high rail-mounted gabbards. The diametral girder was first erected, on staging, working outwards from the central pivot. The "chord girders" forming the tower bases were then erected, again on staging, and the bogies inserted under them. Then the towers were erected, carefully checked, and riveted.

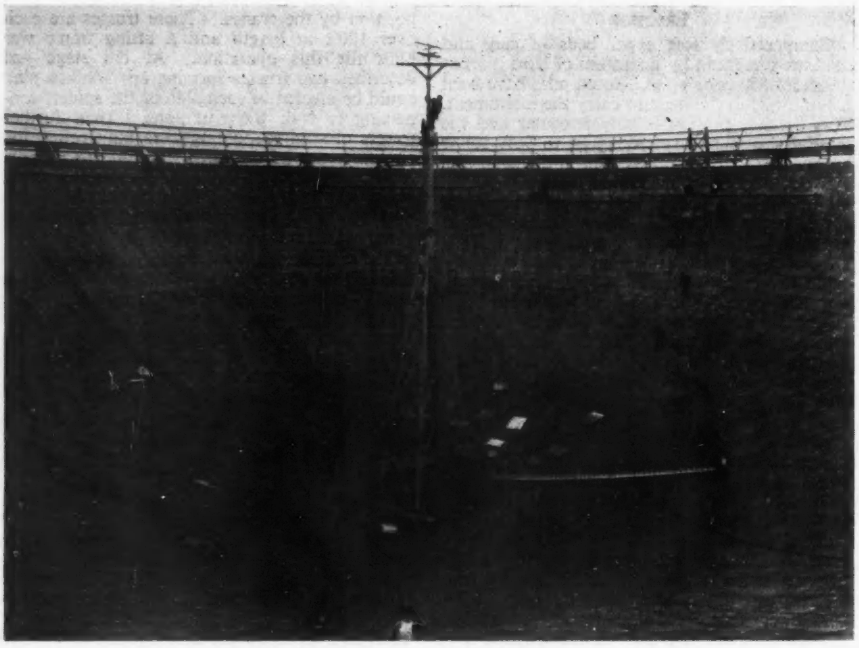
A tower of steel scaffolding was then built over the central pivot, and the "spider" of the bowl structure was erected on it. By this time the trunnion bearings had been erected on the towers, and the adjacent circumferential steelwork was added, from scaffolding built up by each tower. The radial K-trusses were assembled at ground level, and successively lifted into position by the cranes. These trusses are each over 100ft in length and a lifting frame was built for this operation. At the stage just described two trusses forming an "A" in plan could be erected in each side of the spider, connecting it with the trunnions. Then further towers of steel scaffolding were built round the circumference of the bowl structure, to support each panel point of the outer ring of steelwork, and assembled K-trusses were afterwards hoisted up, proceeding fanwise from the trunnions, to complete the space frame.

The scaffolding, as can be inferred, was somewhat elaborate and 750 tons of steel tubes were needed; 3in tubes were used for the uprights and 2in tubes for other members. Screw jacks were built into the scaffolding towers to compensate for deflection at the top of the tower as deadweight was added. Erection at the top of the towers was set out to compensate for the deflections of the permanent steelwork when it eventually sustained its working load, so that the specified paraboloid would be accurately formed.

Detailing of the steelwork was unusually onerous, both on account of the high degree of accuracy called for, and the unusual shape of the structure. An idea of the complexity of this aspect of the work may perhaps be given by referring to the purlins. There are 2200 angle-iron purlins carrying the surface of the bowl. Each had to be curved to different diameters in two planes, so that a purlin lay truly on the surface, with one side of the angle iron parallel to it.

The bowl consists of 3ft by 3ft steel plates of 14-gauge steel, continuously welded to these purlins and also continuously welded together

The general form of the space frame which carries the telescope's bowl is well shown in this illustration, and the importance of small deflections in its design can be inferred from the great depth of the trusses. The circular beam in the centre damps oscillations due to wind



The interior of the telescope's bowl gives a good impression of the size of the instrument. Note the aerial carried on a steel mast 62·5ft high

along their edges. Each plate is stiffened and is flat. Over 7000 plates will have been used to complete the bowl.

It was found that this steel plate surface was far more satisfactory than the original design, which envisaged a strained copper wire mesh. Electrical conductivity of the bowl, as constructed, is satisfactory, and it also shields the telescope against extraneous radiations coming from behind. The requirements for painting the bowl are somewhat unusual. The paint must prevent a serious concentration of heat, by reflection, at the focus of the paraboloid. And it must also encourage a high degree of diffuse reflection of the sun's rays, so that the steel membrane itself does not get too hot. A synthetic flat white paint is specified.

Mechanical Engineering Design

Temperature movements in the structure of the radio telescope are allowed for in a strikingly simple way. The lower part of the structure is held only at the central pivot, and so can expand and contract from that point. The bowl structure when expanding, exerts a thrust on the towers, which is taken up by the trunnion bearings and by deflection of the towers themselves.

The central pivot and thrust bearing, which carries a certain amount of dead load from the structure, consists of two castings, weighing jointly about 13 tons, and set into the massive concrete block already described. The main function of this pivot, however, is to provide a horizontal restraint against wind loads. The pivot castings embody a large double-row journal bearing of 30in bore, which has an outside diameter of 42in and is 7¾in wide.

There are four driving bogies and eight idler bogies, or wind carriages, carrying the telescope in its circular track. Two driving bogies are situated under each of the towers, and the corners of the "outrigger" bracing of each tower are carried on the idler bogies. The rollers of the bogies—there are four in each bogie—are tapered, to give a true rolling path on the curved track, and they rely on friction between the roller and the rail, for their motion. When the weather is calm the driving bogies each carry a load of about 400 tons, but the load on the "outrigger" bogies, of course, varies depending on the wind.

Each of the four driving bogies has an individual driving motor unit, which, in turn, drives the four track rollers, with each track roller coupled by idler gears. These spur gears were cut with a slight taper on the teeth to accommodate radius on the track. The driving bogies each weigh 16 tons, and the idler bogies 13½ tons. All bogies can be clamped to the track.

Each bogie comprises three sections, a centre frame and two end frames, with each end frame bored for 7½in diameter pivot pins, to pivot about each end of the centre frame. The rollers comprise cast iron centres with forged steel tyres shrunk on, each one being machined with a taper on the tyre for the inner track of 0·188 in 12in and for the outer track 0·170 in 12in. Each roller was also bored to take one ball location bearing and two roller journals. In the manufacture of the bogies the body plates were fabricated from 2in mild steel plate for the end frames and 3in mild steel plate for the centre frames.

The trunnions carrying the bowl structure are also worthy of further description. The contractor for the trunnion bearings points out that, although these bearings are not the largest which the firm has made, they have the highest load/diameter ratio of any made by them up to the present. Each bearing is designed to carry a maximum radial load of 500 tons and a thrust load (in either direction) of 125 tons. The illustration opposite shows one of the trunnions. The bearings are of 30in bore and each has four rows of rollers, 2⅝in diameter by 3¼in long, to carry the radial load. The inner and outer races are in two halves to the circle, the inner races being secured to the trunnion by heavy clamping rings.

The bearing assembly on each trunnion is contained within a spherically machined globe housing, which, in turn, is fitted within a bored pedestal. Self-alignment occurs on the housing and pedestal interface. The housing is made in cast steel and the pedestal is fabricated in mild steel; both are split on the horizontal centre line. The pedestal assembly weighs approximately 13½ tons, and the height from the base to the top of the pedestal is 6ft 7½in. The bearings are automatically lubricated with lithium base grease and corrosion inhibiter.

Gearing

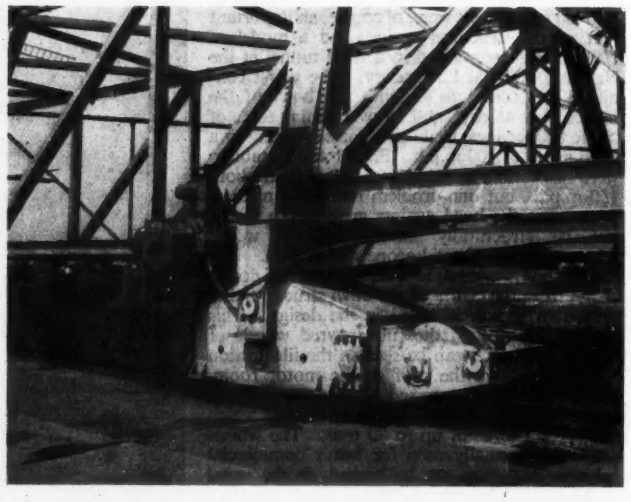
Lubrication of the gearing in the driving bogies and trunnions also presented a special problem due to the fact that the gears might be stationary for long periods in both hot and cold conditions and that, when in operation, some of the gears might run for long periods at speeds as low as one-half revolution per hour.

In each driving bogie, the reduction gearing consists of a standard double reduction spur gear unit followed by larger gears; the total overall reduction from motor to track is 185/1.

At the trunnions, two sets of gears in tandem, each giving an overall reduction of approximately 21,500/1, are mounted in each tower driving on two large internal spur gears integral with the bowl. Unit construction has been followed as far as possible, but the size of individual assemblies has been limited by the fact that all the machinery had to pass through a small aperture at the top of the towers and hoisting facilities were restricted to 3 tons. Each set consists of a standard double reduction spur unit mounted on a bed-plate, together with the driving motor; the output shaft of the unit carries a pinion which forms the first member of a further set of double reduction gears The shafts for these are mounted in pedestal bearings and housed in sheet steel gear cases. The complete weight of the two sets of gearing fitted to each tower is approximately 21 tons.

Electric Motors

The speed of rotation of the telescope, and more particularly the rates of acceleration, are so low that the power required on account of the mass of the instrument is only a small proportion of that needed to control wind forces. Power is generated locally at the site at 415V a.c. It is brought to the motor room situated centrally at the base of the instrument, where two 175kW Ward-Leonard d.c. generator sets, each comprising an a.c. driving motor, a d.c. generator, a main exciter and a control exciter, regulate the power output to the variable-speed d.c. motors, which actually operate the telescope. This equipment can be considered as two identical sets, each of four motors, one for driving the telescope in azimuth and the other in elevation. The four motors of each set are in series, and they each have a tuning resistance to give an initial adjustment so that load is shared equally amongst them. The four azimuth motors are mounted one on each driving bogie, and the four elevation motors, two in each trunnion bearing house. Two of these latter motors are shown in the illustration on page 11.



One of the four driving bogies. The motors are force-ventilated, since their lowest speed is 10 r.p.m. One of the track rollers can be seen, and the method of mounting the twin 109 lb rails on steel plates may be noted

The speed range of these motors is from 10 to 1000 r.p.m. by Ward-Leonard voltage control,

(Left) Roller bearing at the main trunnion of the bowl. The bearing is designed for a load of 500 tons, and a thrust of 125 tons. (Right) Two forced-ventilation 50 h.p. motors and reduction gearing at the trunnion for turning the bowl

and from 1000 to 1500 r.p.m. (for the occasional fast traversing of the telescope) by weakening the motor field. The motors drive through the series of high-ratio reduction gear trains, already described.

The control exciter output of the 175kW d.c. generator supplies the field of the generator, and the main exciter supplies the four fields of the actual driving motors. The separate field of the control exciter is supplied from an electronic control unit, and the output voltage of the exciter, which will be dependent on the strength of the signal, is applied to the generator field. This will, in turn, govern the generator output voltage and the speed at which the driving motors will run. The field weakening control at high speeds is carried out by operation of shunt field regulators under automatic control.

The overall system includes a.c. and d.c. control panels, interlocked circuits to prevent the rotation of the telescope beyond definite limits, and to prevent operating under dangerous conditions.

Control of the Telescope's Movements

Control of the telescope is based on : (*a*) measuring its actual position at any given time; this is done independently of the driving system so that errors due to backlash of driving gears and similar causes are obviated ; (*b*) calculation of the required position at the given time. The difference between the two—the "error" signal—is fed into the control system of the driving motors. These various measurements are shown on dials in the control room, where all such information is grouped on two panels and the control desk.

To transmit the precise position of the telescope on its two axes back to the control room very accurate mechanical drives had to be arranged. One of these is situated at the centre pivot and the other at one of the trunnions carrying the reflector bowl. In the latter, a standard roller chain encircles the trunnions and meshes with a chain pinion on the magslip operating shafts for the precise indication of every movement of the bowl. Within these drive units is a device to eliminate backlash and this is also chain driven.

The required position of the telescope is continuously calculated by an electro-mechanical analogue computer governed by a sidereal clock, built into the control room panels. Equations for the path of a star are thus converted into azimuth and altitude instructions for the telescope. The required position of the telescope in terrestrial, celestial and galactic co-ordinates is indicated in the control room and the actual position of the telescope itself is also shown, all to one minute of arc. In addition, outputs are provided for other remote indicating and recording apparatus.

The "error" signal between required and actual position is fed into the electronic controller in the motor room, which determines from this information the speed at which the motors are to run. The controller utilises a closed loop servo system, with an amplification between the signal power and the motor power of 30,000,000 to 1. Except for high-speed traversing, the overall accuracy is about twelve minutes of arc.

Damping Vibrations Due to Wind

The central ring beam which transmits damping forces to the bowl structure has already been mentioned, and the principle of using rubber-tyred wheels rolling on it, which are braked when damping is needed, has been explained. The beam is 280ft in diameter and is at right angles to the axis of rotation of the bowl. It is strutted to the bowl in a manner not unlike the spokes of a bicycle wheel. Two pairs of heavy duty axles, of the kind normally used for heavy commercial vehicles, are used to apply the damping forces. Each pair of axles carries four pneumatically-tyred wheels. There are two adjustments for the system : (*a*) jacking the wheels on to the flanges of the beam, and (*b*) braking the wheels. The latter is the normal control for damping ; the brakes are hydraulic and are remotely controlled, this control being fully interlocked with the operation of the controls for rotating the bowl.

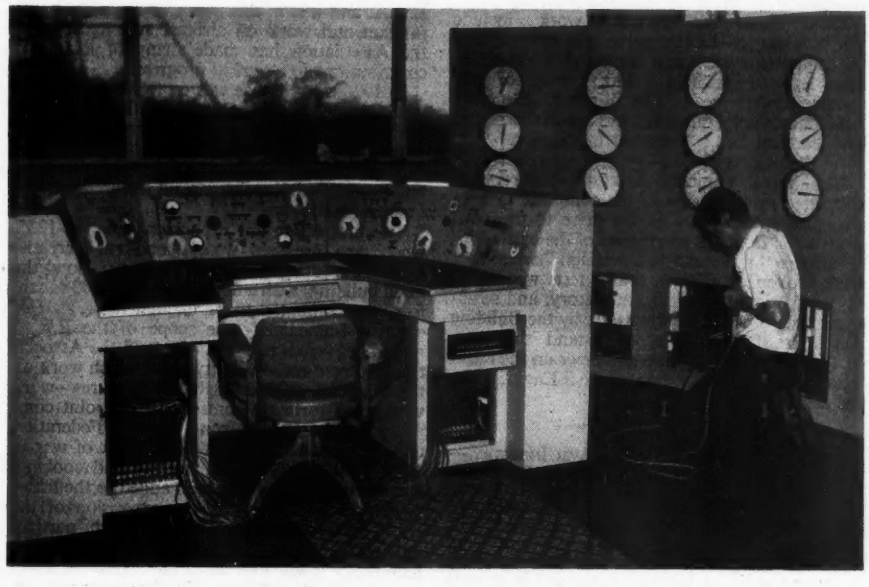
Briefly, the equipment consists of a centralised power pack with piston accumulator, the pump motor being controlled automatically by the pressure variation of the system. Thrustor-operated valves interlock the hydraulic circuit with the telescope drive controls; indicator lamps provide visual indication of "brakes on" or "brakes off" if required. The whole of the power equipment is housed within the central motor room. Pipe-lines are run out from the motor room to each four-wheeled bogie, the actual brakes being operated by four high-duty cylinders.

A somewhat similar system of damping is to be used for the cabin which is freely suspended below the centre of the bowl. In this case, however, the brake will be controlled by the occupant of the cabin.

Operation of the Telescope

Operational tests have still to be carried out to determine the telescope's behaviour under high winds, and the practical limits of its operation by weather conditions.

When it is being used to receive radiations from outer space the amount of energy concentrated on the aerial at the focal points is extremely small. In order to amplify and analyse these radiations before they are dissipated or contaminated by local atmospheric disturbances or man-made radio waves, it is desirable that the radio receiving set, which may roughly be compared to a television receiver, should be as close as possible to the aerial. For some purposes the first amplifier will be immediately adjacent to the aerial at the summit of the 66ft tower in the centre of the bowl, but the main amplifiers are suspended in the steel laboratory hung immediately below the centre of the bowl itself. This labora-



Control desk of the radio telescope and one of the computer panels

tory is suspended on trunnions in order to keep its floor level and its damping device was referred to above. The suspended laboratory can be reached by gangways from the top of each bearing tower, where further high-level laboratories travel round with the azimuth motion of the telescope. Each tower contains an electrical passenger lift and also a hoist for handling mechanical equipment to the motor rooms. Much of the high-level mechanical and electrical equipment was installed under difficult conditions of access.

The termination of the main feeder cable at the telescope end provided a technical problem of some interest, due to the fact that the conductors had to be taken from a fixed point at the centre of the structure on to the moving portion. Any form of slipring and collector assembly was considered to have adverse effects on the various radio measurement cables and devices, and was therefore prohibited. A cable turning device was therefore designed. The cables are hung in loops from fixed brackets, placed in the motor room at the centre of rotation of the instrument, and as it turns the movement is taken up by the loops to the extent of 400 deg. of rotation.

Firms Responsible for Design and Construction

The radio telescope is owned and is to be operated by Manchester University, and the original conception of the instrument is due to Professor A. C. B. Lovell, F.R.S., professor of radio astronomy at the university ; he will direct the researches for which the telescope will be used. The consulting engineers responsible for its design and construction are Messrs. Husband and Co. The main contractor for the structural work is the United Steel Structural Company, Ltd. The Brush Electrical Engineering Company, Ltd., is the main electrical contractor. The estimated cost of the complete project is about £750,000. The Department of Scientific and Industrial Research and the Nuffield Foundation have both made grants towards the cost.

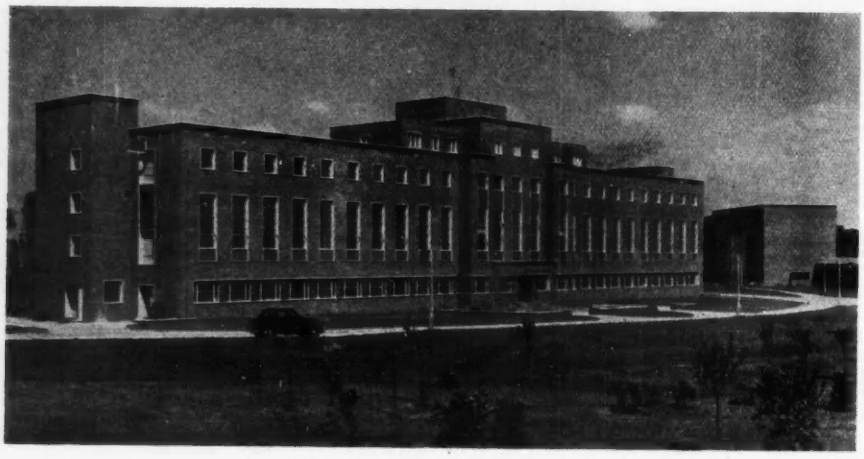
Other civil and mechanical engineering contracting firms who have made substantial contributions to the radio telescope are as follows :—Foundations, Cementation Company, Ltd. (piles), and W. T. Whittall and Son, Ltd.; rail tracks, T. W. Ward, Ltd.; bogies, B. Thornton, Ltd.; centre pivot, Davy and United Engineering Company, Ltd. and Hoffmann Manufacturing Company, Ltd. (bearings) ; steelwork erection, Cozens and Sutcliffe, Ltd., and Orthostyle, Ltd. (steel plate lining of bowl), and Mills Scaffolding Company, Ltd. (steel scaffolding) ; main trunnion bearings, Cooper Roller Bearing Company, Ltd.; gearing, Alfred Wiseman and Co., Ltd.; damping axles, Kirkstall Forge Engineering, Ltd., and Dunlop Rubber Company, Ltd. (tyres) ; hydraulic control system for damping gear, The Automotive Products Company, Ltd. (Lockheed Industrial Hydraulics Division).

Other firms for electrical work include the following :—Development and manufacture of computer system and control desk, Danford and Elliott (Sheffield), Ltd.; part of the motor control gear, The Watford Electrical Manufacturing Company, Ltd., and Dewhurst and Partner, Ltd.; electrical installation work, F. H. Wheeler and Co., Ltd.

The Naval Gunnery Research Station was consulted in the design of the computer system. The final spur wheels on the drive to the bowl were taken from the gun turrets of the battleships " Revenge " and " Royal Sovereign " when they were broken up. Wind tunnel tests were done by the National Physical Laboratory, and structural tests are being carried out by the Building Research Station. We understand that Mr. H. C. Husband is to present a paper on the radio telescope at the Institution of Civil Engineers in the next session.

Research for the Sand and Gravel Industry.—The Sand and Gravel Association of Great Britain has now completed arrangements for research into its products and production problems. The work will be carried out in co-operation with the Cement and Concrete Association, and be controlled by a panel under the chairmanship of Mr. B. L. Morton, O.B.E. A research staff has been appointed and is to start work at the research station of the Cement and Concrete Association this month.

Electrical Research Laboratories at Leatherhead



The new laboratories of the Electrical Research Association at Cleeve Road, Leatherhead, were opened on June 26 by Lord Mills, the Minister of Power. These laboratories, which include a high-voltage laboratory, absorb part of the work formerly done at the E.R.A. laboratories at Perivale, which are being retained together with the field station at Shinfield for work on rural electrification, as well as the wind power testing station at Cranfield. An outline of the new laboratories, and of some of the work which was demonstrated on the opening day, is given here.

THE opening of the new research laboratories of the Electrical Research Association (E.R.A.) at Cleeve Road, Leatherhead, marks the completion of forty years of co-operative research in the British electrical industry. For it was in 1917 that the Electrical Research Committee (the forerunner of the E.R.A.) was formed by the Institution of Electrical Engineers and the BEAMA to take over the research work formerly handled by the research committees of those bodies. Three years later the E.R.A. was incorporated as a research association.

Initially all research was extra-mural and since the early days the E.R.A. has made full use of the facilities offered by the National Physical Laboratory, the universities and technical colleges and other centres of research. Direct research by E.R.A. staff was started in 1921 at Carville power station, where a generator was made available for work on switchgear. Since then switchgear has provided one of the main research interests of the E.R.A. and it is in this field (for example, by its fundamental work on airblast switchgear) that the Association has made many of its major contributions to electrical progress.

In 1926 a test house was established at Stonebridge Park, where the main traction battery of the then L.M.S. Railway was made available for research on fuses. Four years later switchgear research was moved from Carville to Acton Lane and a small building for general research was put up on a nearby site.

The first important expansion came in 1935, when new premises were opened at Perivale, where the original accommodation (now the main building) with a floor space of 14,000 square feet, was estimated to be enough for a staff of eighty. Immediately the scope of the E.R.A. researches began to grow. In 1935 the Association accepted responsibility for research work on the creep of steel at high temperatures—work which was formerly controlled by a joint committee of the British Iron and Steel Federation and the E.R.A. Before the outbreak of war in 1939 rural electrification, heating and cooking, and electrical safety had been added to the list of researches and there was an expansion of the effort devoted to fundamental research, particularly at the universities and the N.P.L. Further laboratory space was soon an urgent necessity and, despite the addition of a three-storey building (which doubled the accommodation) and the erection of prefabricated huts, it became clear that the 1¾ acre site at Perivale would be inadequate in the post-war years.

In 1943, therefore, the council of the E.R.A. bought a site of about 48 acres at Leatherhead, in an area which was scheduled for light industrial development. The first scheme for the new laboratories, at a cost of £1,000,000, was prepared in 1946, but, although this scheme was accepted as an ultimate target, modified plans were drawn up for an initial development estimated to cost £600,000. These plans omitted the high-power building (there were technical reasons for its deferment) and accommodation for the non-technical services which were already installed at Thorncroft Manor. A further revision was decided upon in January, 1950. By allowing for part of the research organisation to be retained temporarily at Perivale and by retaining the field station for rural electrification at Shinfield and the temporary station for wind power tests at Cranfield, instead of transferring all these activities to Leatherhead, the estimated cost was reduced to £400,000.

To provide this sum, the E.R.A. council set aside £100,000 and about £203,000 was raised by an appeal for capital contributions from E.R.A. members on the understanding that, provided this appeal produced £200,000 the remainder of the cost would be met by a capital grant up to £100,000 from the D.S.I.R. The main contract was placed with Gee, Walker and Slater, Ltd., London, in December, 1953, and the new buildings were occupied in June, 1956.

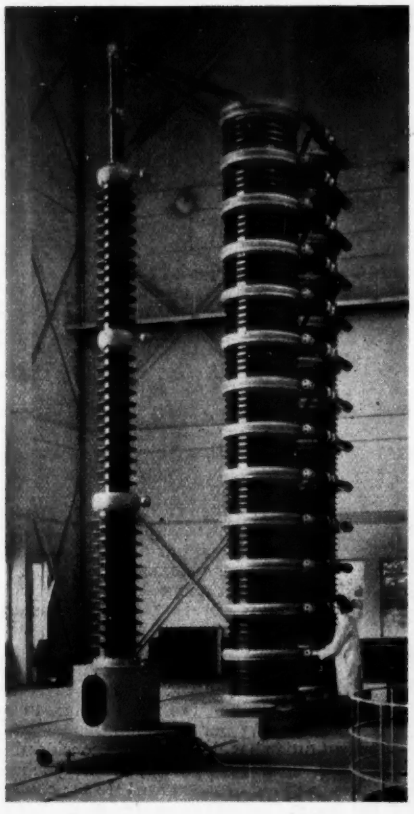
The present development planned by Mr. Herbert J. Rowse, F.R.I.B.A., consists of three buildings. The main building has three floors and a mezzanine floor and houses a number of standard, functionally interchangeable laboratories and a library, a photographic department and offices. There is also a high-voltage building which can be seen to the right of our first illustration. The third building houses a workshop and contains separate accommodation for a canteen. As illustrated, the main building consists of a central section with two main wings (north and south) on the same elevation and a third wing at the back of the central section on the west elevation. The ground floor and the second and third floors of the central section and its north and south wings are of normal height. Much of the first floor has a height of 18ft and

the remainder is covered by a mezzanine floor. Work requiring greater headroom can, therefore, be done on the first floor while the mezzanine floor (as can be seen from some of the illustrations) provides an observation platform with additional working space. In the west wing there are three floors of normal height.

Space for twelve standard laboratories, each 50ft by 35ft, is contained in the north and south wings and there are three similar laboratories in the west wing.

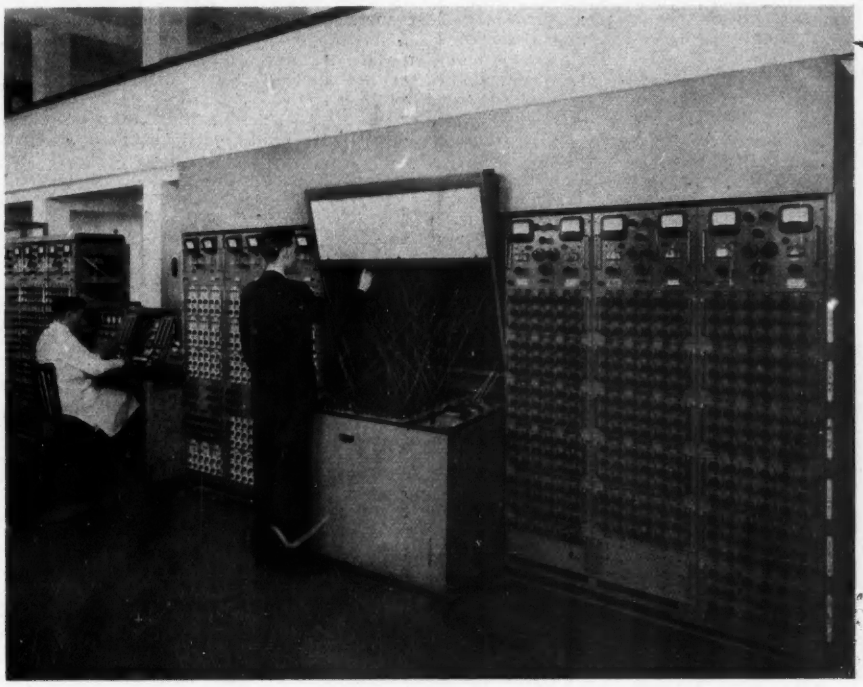
The high-voltage building consists of a central high-voltage hall with a floor area of 100ft by 50ft and a height of 50ft, flanked by wings of normal height to house a transformer, laboratory, generator room, instrument room, photographic dark room and offices. The central hall accommodates a 2,800,000V impulse generator, a 1,300,000V impulse generator, a 50 c/s test transformer, a high-current surge generator and high-voltage d.c. test equipment. This plant covers all the test requirements appertaining to the highest supply voltages in use or envisaged at present. There is an outside test area, equipped with floodlights, where impulse tests can be done on high-voltage equipment or on equipment that is too large to be tested inside the laboratory. Test voltages can be transmitted to this outdoor test area through large power-operated folding doors fitted to the laboratory building.

The larger of the two impulse generators can be arranged in either of two ways. In the form in which it is at present assembled, as illustrated



2,800,000V impulse generator with thirteen stages and a maximum stored energy of 130kW-seconds, suitable for tests on transmission equipment such as cables and transformers

here, the equipment consists of thirteen stages arranged in two columns, with an output capacitance of 0·033μF, giving a nominal output voltage of 2·8MV, and a maximum stored energy of 130kW-sec. It will be possible to rearrange the equipment in four columns, giving six stages with an output capacitance of 0·14μF and a nominal maximum output voltage of 1·29MV. With these facilities the impulse generator should be particularly useful for research work on very-high-voltage transmission equipment, including transformers and cable samples requiring high input energy.



Network analyser. One-quarter of the complete equipment is now in operation. It can be operated over a frequency range of 100 to 1 about a base frequency of 1592 c/s in transient or steady-state conditions

The second impulse generator has twelve stages, with an output capacitance of 0·01μF, giving a maximum stored energy of 8·5kW-sec at a nominal maximum output voltage of 1·3MV.

For impulse tests requiring lower energy and voltage there is also a smaller impulse generator of five stages having an output capacitance of 0·01μF, with a maximum stored energy of 200W-sec at a nominal maximum output voltage of 200kV.

The measuring equipment includes 200cm diameter spheres, with hydraulic adjustment of gap, for peak voltage measurement. A mobile tower gives access to the roof and walls of the building for adjustment and maintenance of the high-voltage circuits.

Examples of Researches

A few examples of work in progress are briefly referred to here, to give some impression of the scope of the Leatherhead laboratory's activities.

Work on transformers includes the study of axial electromagnetic forces and for this work experimental transformers have been designed so that the dimensions can be measured precisely, and any of the more usual arrangements of tappings can be obtained. Each transformer has two similar disc windings and accidental axial displacement between windings is avoided by using spacing sectors common to the two windings. The two transformers are similar in all proportions except for the ratios of window-height to core-circle diameter, which represent maximum and minimum values. Curves taken on the larger transformer illustrate the effect of tapping arrangement on axial forces.

One of our illustrations shows a network analyser which is under construction in stages in the first floor of the main building. At the present stage one-quarter of the complete equipment is fully operational. It is unique in that it is designed to be operated over a frequency

An insulation laboratory in the main block. Here the electric strength of solid dielectrics is studied

range of 100 to 1, about a base frequency of 1592 c/s in either steady-state or transient conditions. A typical example of the application of the analyser on power systems was its use in a series of transient-stability tests carried out at Cliff Quay power station in August, 1956. One facet of this work which was seen during our tour of the laboratories was a graphical representation of the Eastern Division of the Central Electricity Authority showing the determination of the restriking voltage transient at the interruption of a balanced short circuit at Cliff Quay.

Heat flow problems in two dimensions can be investigated on the network analyser. For example, by representing the thermal resistance and capacitance of a body by a suitably proportioned network of capacitors and resistors, the temperatures and temperature gradients resulting from rapid heating may be studied. The results of an investigation into the temperature gradients in two dimensions in an aircraft wing section were shown during our visit.

A typical first-floor laboratory for work on dielectrics can be seen in one of the accompanying illustrations, which shows part of the gallery on the mezzanine floor. The work on solid dielectrics includes studies of the intrinsic and electromechanical breakdown of polythene and other materials, and the dependence of electrical discharge characteristics on dielectric surface conductivity. Apparatus has been developed for frequency-accelerated life tests to determine the corona resistance of sheet insulation.

Theoretical and experimental investigation of arc temperatures are being carried out in a room on the first floor of the west wing. Here a study of the changes of the arc form and temperature which occur with changes in current has resulted in a purely thermal theory of the development of the successive luminous cores which appear with increase of current and of axial temperature. These temperatures are much higher than had previously been considered, and under special conditions reach 50,000 deg. K. This work is of importance in researches on circuit breaking, welding, fuses, contactors, searchlights and in spectrochemical analysis.

In the same laboratory there is a miniature experimental gas-blast circuit breaker, specially designed for spectroscopic and optical studies of the electric arc in rapidly flowing gas. It can be arranged as a single, double or duplex blast circuit breaker, using various gases or gas mixtures. The introduction of a spark-initiated discharge of a bank of capacitors has greatly accelerated the speed of testing, and is capable of operating at 1000 tests per hour with automatic recording of various electrical phenomena.

Another laboratory is devoted to work on electrical equipment for automotive systems. Here, for example, the possibilities of surface discharge sparking plugs are being explored. This work springs from the fact that increased operating voltages of I.C. engine ignition systems, required for the higher compression ratios, create serious insulation problems, particularly in screened systems. Low-voltage surface-discharge sparking plugs have proved to be little affected by pressure and relatively free from fouling, but a number of difficulties have yet to be overcome.

An allied piece of research concerns contact erosion, which governs the reliable operation of many circuits in light current engineering. Particular examples are the contact breaker in the ignition system of an I.C. engine and the current and voltage controls in battery charging regulators. The E.R.A. is studying the processes which occur during the operation of current-carrying contacts, particularly with regard to residual transfer and the effects of very short duration arcing which occurs in low-inductance circuits. This work, and the research on surface-discharge sparking plugs, receive special contributions from the Ministry of Supply, Fighting Vehicles Research and Development Establishment.

A new design of capacitor based on aluminium oxide film is being developed as a result of work on the physics and chemistry of materials in a room on the second floor. This capacitor has a small volume and wide range of operating temperature (<-180 deg. Cent. to $+120$ deg. Cent.). The dielectric consists of an anodically-formed oxide film 0·2 to 1 micron thick on aluminium foil, the other electrode being a thin evaporated layer of aluminium having self-healing properties. No electrolyte is present in the final assembly, and the capacitor will operate on alternating current. Maximum working voltage is up to 200V d.c. or a.c. peak.

The breakdown strength and other properties of oxide films formed on aluminium by different anodic processes are also being studied. This work is of practical interest in connection with the possible use of anodised aluminium conductors for windings.

The role of absorbed moisture in determining insulation resistance, power factor and breakdown strength of cellulose and alumina, especially at very high stresses, is being investigated. This basic study may help to solve problems connected with discharge inception and breakdown of dielectrics.

Institution of Engineers and Shipbuilders in Scotland

ON May 1, the Institution of Engineers and Shipbuilders in Scotland was 100 years old, an achievement which was noted on page 706 of our issue of May 10, when we reprinted the announcement which appeared in THE ENGINEER of May 8, 1857. To mark the occasion the Institution received congratulatory messages and presentations from technical societies in this country and all over the world. These included a silver-mounted gavel and stand from the North East Coast Institution of Engineers and Shipbuilders; the Scroll of Honour of the American Society of Civil Engineers, and a certificate from the Scientific Society of Shipbuilders of the U.S.S.R., while Sir Wilfred Ayre presented a president's badge. During last week a meeting was held in Glasgow to celebrate the centenary and was attended by delegates and their ladies from many countries and from the learned societies in Great Britain, in addition to the Institution's own members.

The meeting opened on the morning of Tuesday, June 25, with a technical session in the Rankine Hall at the headquarters of the Institution, while the ladies made a tour of the City. In the afternoon the members paid visits to shipbuilding and engineering works, and in the evening a banquet and dance was held in St. Andrew's Halls. At the dinner Lord Boyd Orr proposed the toast of "The Institution of Engineers and Shipbuilders in Scotland," and Sir Harold Yarrow, Bt., the president of the Institution, who responded, also proposed the toast of "Our Guests," on whose behalf Monsieur Augustin-Normand replied. Wednesday was occupied by an all-day cruise down the Clyde on board the "Queen Mary II," while on Thursday the delegates paid all-day visits to shipbuilding yards and engineering works. The ladies spent the day either visiting Edinburgh or touring the Trossachs, and the centenary celebrations were concluded by a civic reception in the City Chambers at the invitation of the Lord Provost and Corporation of the City of Glasgow.

Technical Session

At the technical session on Tuesday morning the president, Sir Harold Yarrow, Bt., welcomed the delegates and gave his presidential address, of which the following is an abstract.

Presidential Address

The origin of the Institution was due chiefly to a summer meeting held in Glasgow in 1856 by the Institution of Mechanical Engineers, at which a large quantity of machinery by Glasgow makers was exhibited. These proceedings produced the impression that a society of engineers holding its meetings in Scotland, and in Glasgow, would be successful, and at the meeting on May 1, 1857, "The Institution of Engineers in Scotland" came into existence.

The first president was Professor W. J. Macquorn Rankine, and the vice-presidents were James R. Napier, Walter M. Neilson and H. Neil Robson. The first presidential address was "On the Nature and Objects of the Institution."

When the Institution commenced it had 127 members. By the beginning of the third session there were about 150 members on the roll, and the new Institution was being looked upon with increased favour by the industry as it progressed. But even as early as that third session the president, Mr. Walter Neilson, had reason to make the following comment in his address :—

"There are many members on our roll who never attend our meetings; many cannot conveniently do so whose names we are glad to have. But there are others who content themselves with our transactions, and imagine they obtain all the benefit that others do who attend regularly. This is a great mistake . . . Can any one say that meeting as we do to interchange the knowledge and experience we daily gain, we do no good?"

Linked up with the early history of the Institution of Engineers is that of the Scottish Shipbuilders' Association, which was formed as a separate body in 1860. It must have been a fairly lively and controversial body, because its opening paper, given by Mr. Robert Mansel, "On the Comparative Strength of Iron Ships," was immediately followed on the syllabus by Mr. George Barber's paper "On the Weakness of Iron Ships"!

In 1864, the Institution of Engineers and the Scottish Shipbuilders' Association decided to amalgamate. A meeting was held on April 26, 1865, at which the proposed amalgamation was unanimously approved, and Mr. J. G. Lawrie was elected first president of the united body. The title of the Institution was accordingly changed to "The Institution of Engineers in Scotland, with which is incorporated The Scottish Shipbuilders' Association." In 1870 it was agreed that the title of the Institution should be "The Institution of Engineers and Shipbuilders in Scotland."

In 1878 the lease of the buildings then being used lapsed, and sketch plans and estimates for a building in Adelaide Place, Bath Street, were prepared, negotiations being made with the Philosophical Society of Glasgow on the basis of a joint association with that body, the ground and buildings to be held in joint proprietorship by the Institution and the Philosophical Society. The building was eventually erected and occupied by the two societies in 1880.

In 1905, with a membership of about 1450, it was decided to sell the Institution's share in the building and look out for new premises, and the recommendation to acquire premises in Elmbank Crescent was adopted.

Between the two world wars the number of members declined and by 1937 it had fallen to about 1200, but to-day membership has risen to about 1400. I suggest that still greater efforts should be made to impress on the young engineers and shipbuilders of to-day the advantages to be obtained in joining our Institution.

The Institution has always taken a considerable interest in the proper training of the younger members of the profession. In 1918 the council set up a special committee which presented its first report in 1920, a second report being published in the following year. These reports were of such value that when in 1944 the Advisory Council on Education in Scotland turned its attention to technical training, the Institution was invited to submit copies. Although these had been compiled twenty-five years earlier, they were found to be still applicable.

An interesting function in our annual programme is the "James Watt" Dinner at which the toast to the memory of James Watt is drunk in silence. This dinner appears to have originated with a small number of foremen engineers and eventually was held yearly under the joint auspices of this Institution, the Philosophical Society, and the Association of Foremen Engineers. Later the other societies withdrew, and to keep alive the name it was applied to the annual dinner of the Institution.

In 1919, a sum of over £30,000 was raised for the purpose of commemorating the life and work of James Watt, and this was used to convert the two existing lectureships at the University of Glasgow into "James Watt" professorships of Electrical Engineering and the Theory and Practice of Heat Engines, this latter being subsequently renamed the Chair of Mechanical Engineering. As far back as 1863 a committee was appointed to raise funds to endow a lectureship in Naval Architecture and Marine Engineering in memory of John Wood, the Port Glasgow shipbuilder, but insufficient funds were obtained. In 1883, however, Mrs. Elder endowed a Chair of Naval Architecture in Glasgow University in memory of her husband, John Elder.

I should now like to dwell on some of the interesting papers and reports produced over the last 100 years, some of which are still proving their practical value. In the *Transactions* of the early sessions there is evidence of the many problems which confronted the industry at that time. The change-over to iron ships, for example, was presenting serious difficulties. The unpleasant vibration of some propellers was disturbing, and the search for economy in the marine and railway fields was beset with difficulties. Measurements of the various elements constituting the power generated, the steam produced, the fuel used and the other information needed were very difficult. Knowledge of what constituted the proper basis of comparison was lacking. Efforts to improve the marine steam engine's economical performance were met by unexpected difficulties in the boiler and in the condenser.

During the session, 1865–66, a committee was formed to draw up and transmit to the Board of Trade a memorial on "The Measurement of the Registration Tonnage of Ships," and a discussion on Lloyd's Proposed Rules for the construction and classification of composite ships also took place. Another report which proved of great practical value to marine engineering in those days was in regard to safety valves. In 1872–73 two papers on safety valves were presented, and as a result of these two papers, a special committee was appointed to consider the whole problem. A report was sent to the Board of Trade in 1874 and had a profound influence on marine engineering practice.

Mr. William Denny, in 1874, gave a paper "On the Difficulties of Speed Calculation," while, in 1867, a paper was read by Mr. H. C. Lobnitz "On the Nature and Progress of the Works of the Suez Canal"; and it is interesting to find in 1883, sixteen years later, Mr. James Reid remarking in his presidential address of the difficulties being encountered by shipping in the Suez Canal. "The apparent hopelessness of getting them adjusted or removed," he said, "has naturally turned the attention of British shipowners to alternative plans of maritime communication between the two seas."

In 1893 Mr. John Inglis, in his presidential address, said: "It has been well said that the prosperity of each of us is inextricably bound up in the prosperity of every one else, and the manner of increasing our own gains is not to lessen the gains of our neighbour, or to put obstacles in the way of his enrichment, but rather to contribute to his success in the full assurance that a portion must overflow towards the reservoirs of others"

Throughout the years, our Institution has enjoyed cordial relations with the other technical societies of the country. First, there is the Institution of Naval Architects, who paid their initial visit to Glasgow as guests of the Institution in 1877. They visited us again in 1913, and more recently during session 1944–45.

We have also had happy associations with the North East Coast Institution of Engineers and Shipbuilders, who, in 1909, were our first guests in this building. We again had a visit from that Institution during session 1926–27, and a joint meeting of our two societies was held in Holland in June, 1930. The third society which I have in mind is the Institution of Mechanical Engineers, from whom we had a visit as far back as 1879 and as recently as 1947.

Although I have referred to extracts from certain presidential addresses and papers, especially in the early days of the Institution, I do feel, however, that the spirit of the Institution has never been better summed up than in the address given by Sir James Lithgow during his Presidential year, 1930–31. In view of the depression in trade at that time, Sir James took the opportunity of impressing upon the Institution its responsibilities. He said:

"Success must depend upon the extent to which each is prepared to do his or her part in a spirit of cheerful co-operative endeavour . . .

"We have also a very direct and definite responsibility, by the development of our knowledge of technical matters, to do our share in the placing of our industry in the most advantageous possible position from a technical point of view . . . "

During the last 100 years progress in all aspects of engineering and shipbuilding has been remarkable, but if the rate of development continues to increase, what of the future? We are on the threshold of the atomic age, with its beneficial prospects, automation is on the increase and many new materials are being produced. There is a great challenge to the members of our Institution to contribute to the vast possibilities of these new discoveries and developments and to direct their application to the welfare of mankind.

Following the presidential address a paper entitled "The Institution's First President, William John Macquorn Rankine" was presented by Professor J. Small. An abstract follows.

It is appropriate that we should on this occasion think of the man who, 100 years ago, led the movement for the establishing of this Institution, defined its aims and was fittingly chosen as its first president.

William John Macquorn Rankine was no ordinary man. His place in the history of science as a mathematical physicist is secure, and there are few, if any, who can compete for his place as a pioneer in the application of science to the practical arts. Also in the education of the professional engineer he laid down the lines to be followed and these still have a controlling influence on methods of technical training.

He was born in Edinburgh on July 5, 1820, and Lewis Gordon says, "at the early age of fourteen Rankine had begun to discipline his mind and train his analytical powers on Newton's model of unquestionable definition and exhaustive demonstration, characteristics of the many works on cognate subjects he was himself in after years to contribute for the education of engineers of very class, and for the advancement of physical science."

In 1836 he studied practical and theoretical chemistry under David Boswell Reid, and entered Edinburgh University, where he became a student in the classes in Natural Philosophy, Natural History and Botany. Professor Forbes, the distinguished physicist of his day, awarded the sixteen-year-old Rankine the gold medal for an essay on the "Undulatory Theory of Light," and in the following year presented him with a special prize for an essay on "Methods in Physical Investigation."

In 1838 he became a pupil of a civil engineer and for four years was employed on schemes for river improvements, waterworks and harbour works, and on the Dublin and Drogheda Railway. It was at this time he contrived the method of setting out curves which became known as Rankine's method.

While still twenty-one or twenty-two years of age he sent papers to the Institution of Civil Engineers, and one of them has a bearing on the problem of fatigue of metals and deals with the fracture of axles. Timoshenko alludes to this work as "perhaps the first English paper in this field."

He applied himself to studies in molecular physics, which resulted in a series of papers which were communicated to the Royal Society of Edinburgh, the Royal Society of London and elsewhere. In these for the first time a general equation of thermodynamics was deduced by applying the principles of dynamics to a hypothesis as to the constitution of bodies, and a speculation as to the physical nature of a hot body which he called the theory of molecular vortices. It was in 1852 that, in collaboration with John Thomson, he revived the scheme for the supply of water to Glasgow from Loch Katrine. At about this time Rankine was much involved in dealing with technical problems arising in the business of shipbuilding and marine engineering, and in 1853 in co-operation with Napier he designed and patented an air engine: and in Silvanus Thompson's list of patents associated with the name of Lord Kelvin the first item is entitled "Improvements in Electrical Conductors for Telegraphic Communication," and bears the names of William Thomson, W. J. Macquorn Rankine and John Thomson.

From January to April, 1855, he acted as deputy at the University of Glasgow to Professor Gordon, who notes that the lectures were on "Allied Mechanics" and the "Application of Thermodynamics to the Theory of the Steam Engine," and he prepared from his thermodynamic studies the first practical table of the densities of saturated steam. The Engineering Chair was a Regius Chair and had not been welcomed by the University for the reason that it dealt with subjects far removed from the accepted scholarly pursuits. Another reason for the attack upon the chair was the fact that of all the official endowments to Regius Chairs the largest went to engineering., but when the Queen's commission was read on December 3, 1855, appointing Rankine to the Engineering Chair there was no dissentient voice.

Following his appointment as professor, Rankine applied himself among other things to the writing of his authoritative textbooks.

Rankine became an associate of the Institution of Civil Engineers in 1843 and, according to a statement of the late Professor Barr, that Institution refused to grant him full membership even after he had occupied the Chair of Civil Engineering and Mechanics in Glasgow for two years. It is significant that in 1857 he resigned his associateship and in that year with a number of his forward-looking friends took the lead in the setting up of the Institution of Engineers in Scotland.

In the year this Institution was founded James R. Napier communicated to him the results of "a great body of experiments on the engine power required to propel steamships of various sizes and figures at various speeds." Rankine, whose words these are, continues: "From those results I deduced a general formula for the resistance of ships having such figures as usually occur in steamers, which I communicated to the owner of the experimental data; and he has since applied it to practice with complete success."

Napier was one of the founder members of the Institution of Naval Architects and it may be assumed that it was largely under his influence that Rankine joined that body in 1862.

It has been suggested that his idea of the two elements in ship resistance, namely, those arising respectively from what he terms the "stiffness" of the water and from the eddies generated by friction anticipated by twenty years Osborne Reynolds' conception of the viscous and turbulent constituents of fluid resistance.

Great as Rankine's achievements were as physicist and practising engineer, it is yet possible that at the bar of history he will be judged to have been greatest in his development of the education of the engineer and his elevation of the dignity of the engineer's studies.

In 1859 Rankine persuaded the Senate to consider the award of a Diploma in Engineering Science, and late in 1861 the Commissioners said that in their opinion the University could confer no other distinction than a degree, and that engineering was not "a proper department in which a degree should be conferred."! Later he was successful in gaining the Senate's approval for the award of a Certificate of Proficiency in Engineering Science.

In 1870 the engineering students prayed the Senate to institute a Degree in Engineering Science, and Rankine pressed for a B.Sc. Degree in Engineering, and in 1872 the B.Sc. Degree was established. Thus to Rankine is due the introduction, so far at least as Glasgow is concerned, of the Degree in Science in any department of study. This was the man, great in achievement and great in his character, whose memory this Institution is proud this year to honour.

The technical session ended with the presentation of a paper, by Dr. S. Livingston Smith and Dr. J. E. Richards, entitled "Nuclear Power for the Propulsion of Merchant Ships."

LETTERS AND LITERATURE

Letters to the Editor

(We do not hold ourselves responsible for the opinions of our correspondents)

COMPRESSION TESTING MACHINES FOR CONCRETE

SIR,—In his article "Compression Testing Machines for Concrete," published in your issue of April 26, 1957, Mr. P. J. F. Wright gives some interesting data concerning the behaviour of a number of testing machines in commercial use for crushing concrete cubes. Obviously he has been unable to include all the relevant data in one article; the following points, however, appear relevant. Only three cubes were used to obtain an average instead of the more desirable four or six; no variation between cubes in each set of three appears to be stated; and no statement as to accuracy in reading pressure or dial gauge is made.

The latter is probably of great importance, since a gauge can only be read accurately to, say, half a division plus an estimate to a quarter—see *Proceedings, Institution of Civil Engineers*, November, 1954. In several testing machines used by the writer such an accuracy of reading has meant an accuracy of crushing strength varying from ± 3 per cent to $\pm 1\frac{1}{2}$ per cent, depending on the actual strength. Thus the variation possibly due to the error in reading a gauge may be of the same order of magnitude as the error between testing machines. Perhaps the author would give figures as to the accuracy with which he was able to read the gauges.

J. M. PLOWMAN

London,
June 25, 1957.

SIR,—In his recent article in this journal Mr. Wright has underlined certain important features of any good testing machine. All his conclusions apply to machines used for testing either homogeneous or heterogeneous materials in compression, tension or in flexure; but the problem of the self-aligning platen design seems still to be unresolved. From the results given there is doubt as to the true strength of a concrete cube. Furthermore, there is doubt as to what degree the strength of the mass concrete is revealed by such tests. The recommendation that a platen should be used which adjusts itself to the shape of the cube only during the initial stage of the test is certainly not without reason. The writer in fact made such a proposal with a reservation, in a recent article in this journal—"Hydraulic Self-Aligning Seating," August 17, 1956 Pending a satisfactory solution of the problem, departure from what has been the standard method for some years could be unwise

However, it is assumed that Mr. Wright does not consider the results of his series of tests vindicate the standard method of test in regard to the accuracy of assessment of the strength of the material. From the theory advanced it seems clear that by applying the load up to the point of destruction of the sample by means of a platen which will seek those portions of the sample which have the highest modulus of elasticity, the average strength of the cube is ignored. If the strength of the concrete is to be judged by this method a higher safety factor must be used in design than would otherwise be necessary if the average strength was indicated. According to A. G. Tarrant, "Frictional Difficulty in Concrete Testing," THE ENGINEER, December 10, 1954, the spherical seating of a normal testing machine may remain free up to a load of about 50 tons, but it is equally possible that the seating may seize at much lower loads.

Since the failing loads of some samples may be less than 50 tons there is a risk that tests may be carried out without any indication as to whether the seating was "free" or "rigid" at the failing load of the sample. It is suggested therefore that under the recommendations given by Mr. Wright further information is needed to determine a suitable point on the load curve at which the seating should become rigid. Although the spherical seating appears to produce a lower figure of standard deviation, is it not reasonable to suppose that the more uniform and higher strengths indicated are not necessarily due to more uniform and higher sample strengths? If this is so the discrepancy is probably due to unknown losses in testing machines. This must give rise to further doubts as to the accuracy of this method.

A. C. CARTER
Chief Engineer, K.C. Productions.

London, S.W.6,
June 26, 1957.

CENTENARY OF THE FREE-PISTON ATMOSPHERIC GAS ENGINE

SIR,—In your number of June 14 I was interested to read on page 901 the article on the "Centenary of the Free-Piston Atmospheric Gas Engine," as it made reference to the work of James Robson exactly 100 years ago. The experimental engine which he built is described and illustrated in a Memoir written by his son in 1915, and it occurred to me that this might be of interest to you.

You will probably know that Tangyes, Ltd., became associated with James Robson and in 1881 built the first commercial engine, using his patents. We always feel that James Robson has never had the recognition he deserves, in fact it is true to say that he is still virtually unknown in this connection. I would add that this year, 1957, is also of special interest to us, as in the autumn we shall be celebrating our own centenary, and it is our intention to publish a book in which we shall devote quite a lot of attention to the subject of the development of the gas engine.

C. G. TANGYE
Assistant Managing Director (Tech.)

Tangyes, Ltd.,
Smethwick,
June 25, 1957.

[A copy of the very interesting Memoir accompanied this letter. It certainly suggests that James Robson's work has never received adequate recognition.—ED., THE E.]

Book Reviews

Hygrometry. By H. SPENCER-GREGORY AND E. ROURKE. Crosby Lockwood and Son, Ltd., 26, Old Brompton Road, London, S.W.7. Price 36s.

RECENT increases both in the number of different kinds of hygrometers and also of the applications for which they are required have made the appearance of this new textbook on hygrometry most opportune. Moreover the new book speaks with the authority of two authors who have been in the forefront of developments in humidity measurement for many years. Hence the book manifests that close attention to essential detail and the recognition of practical limitations which stems from hard won experience. In one respect however, the time of publication will have a regretted association due to the fact that the principal author, Professor Gregory, died so soon (March 12, 1957) after its completion.

A long introductory chapter contains a description of the essential features of construction and operation of all the common types of hygrometers including those only recently introduced employing electrolytic or capacitance elements. With each instrument is given an assessment of accuracy and a statement of the useful range of application. Notes are also included on the testing and calibration of hygrometers. The vapour pressure of water and ice, the vapour pressure of solutions and the humidity of gases at high pressures are each considered in detail in separate chapters. The treatment is thorough and a readily available store of fundamental information is thus made available. The basic types of hygrometer are then discussed in detail giving in each case a review of the present state of knowledge on their theory of operation particularly in relation to kinetic theory. The errors likely or inherent in each instrument are carefully scrutinised. Experimental information from many workers is marshalled and reviewed. The concluding chapter deals with the problems of time lag in relation to the Assmann and electrolytic hygrometers.

The style and presentation are agreeable and lucid, conveying in many places impressions of the enthusiasm of the authors. Some readers will be left feeling a good deal less confident of their humidity measurements after reading the book than they were before, but they will have been given the basis on which reliable results may be expected.

Books Received

Mechanical Engineering. By R. W. Steed. Robert Hale, Ltd., 63, Old Brompton Road, London, S.W.7. Price 8s. 6d.

Switchgear Principles. By P. H. G. Crane. Cleaver-Hume Press, Ltd., 31, Wright's Lane, Kensington, London, W.8. Price 25s.

Metal Industry Handbook and Directory, 1957. Iliffe and Sons, Ltd., Dorset House, Stamford Street, London, S.E.1. Price 15s.

Farm Mechanization Handbook. Third edition. By T. Hammond Cradock. Temple Press, Ltd., Bowling Green Lane, London, E.C.1. Price 25s.

Industry and Technical Progress. By C. F. Carter and B. R. Williams. Oxford University Press, Amen House, Warwick Square, London, E.C.4. Price 25s.

Handbook of British Refrigeration Material, 1957. Eighth edition. "Modern Refrigeration," Refrigeration House, Victoria Road, Woking, Surrey. Price 25s.

What New Skills will the Future Demand?

By C. B. GIBBS

From the Conference on Automatic Production organised by the Institution of Production Engineers at Harrogate from June 30 to July 3 we print below an abstract from one of the papers. It discusses in particular product design in relation to the human beings that will use the product, and the difficulty or otherwise of learning how to use it. It stresses the importance for engineers to remember that human beings have to operate the things they make.

The Development and Present Status of Behaviour Studies

OBJECTIVE studies of human behaviour are of comparatively recent origin arising as a reaction against the endless and age-old disputations of the philosophers.

But the tendency to speculate, to rely on introspection and opinion rather than experimentally determined fact, is by no means confined to armchair philosophers or the ancients, particularly in the sphere of human behaviour.

Reasons for Neglect of Behaviour Studies

We now have more respect for science and verified fact, but prejudice and tradition can still obscure those facts relating to human behaviour. There are some major reasons for this neglect and these should be discussed and clarified by a few examples, since there are no apparent or logical reasons why they should persist.

Lack of Knowledge.—The main reason for neglect is simply the current lack of knowledge of the extensive literature on measured human behaviour which is now available. This is not surprising, since a recent handbook of *Experimental Psychology* (by no means comprehensive) contained over a million words. The subject is difficult and the practical implications are not readily apparent to managers and engineers, who are rarely trained in the scientific study of man. The inevitable result is that even the old work is rarely known and still less frequently applied.

In a recent case in point, a new, complex and expensive machine was being designed, and it demanded rapid and skilful action at one part of the cycle of operations. In such cases it is best to make a simulator or mock-up of the task, and to make tests on this before settling on the final design. The firm readily accepted this method, but did not at first appreciate the great importance of making frequent and accurate measurements of the course of learning, or of the need to use a large number of representative operators for the tests. They finally agreed to these suggestions, however, and the experiments clearly showed the importance of such measures. Differences of over four to one were found between the ability of the various operators. On average, the operators took five times longer to reach a high level of skill than the training period originally proposed. The original scheme of testing would not have given the proposed engineering solution the fair trial that the later one provided. Much time and expense were saved by making the simulator tests in advance of final design, since the tests pointed to important modifications and improvements of the original idea. But such techniques are still apparently the exception rather than the rule in designing the workers' machines and skills.

Another recent case brought out the great importance of the transfer of skill. Two tasks may be related in such a way that learning the first can give good indirect practice on the second. This makes its subsequent learning easier and gives positive transfer of skill. But in other cases the learning of a first task may actively impede the learning of the second to give negative transfer. These factors proved to be very important in predesign studies of a complex machine where several engineering solutions were possible. These were all tried out on a simulator in advance of design. The men practised on each solution in turn for a uniform period of time. The firm's assumption was that equal training periods on each arrangement would produce equal skill and so permit fair comparisons. But the results were conflicting and the firm sought advice. It was clear, on examining the records, that both positive and negative transfer were affecting the results when men changed between the different arrangements. Equal times in learning were not, in fact, producing equal levels of skill because of the order of presenting the tasks and the transfer effects. Again, the solution was to take frequent measures of the course of learning, and only to test the men on a particular arrangement when a definite learning plateau had been reached. By such measures the most effective arrangement was found. These simple, psychological measurements made a great difference to the final efficiency of the man/machine system. The best arrangement as found by experiment was over twice as good as others which might well have been adopted had their selection been left to chance.

Human learning and the transfer of skill are important now and will remain so in the future. They have been studied scientifically by experimental psychologists for over seventy years, and many of the main determinants have been thoroughly investigated and presented in mathematical form. The skills of the future may well demand that some knowledge, of at least the earlier findings, should somehow percolate through to industry.

Lack of Specialised Responsibility for Skill—The neglect of operational studies in industry is sometimes due to the fact that no one man has specific responsibility for the overall function of machines, considered as the mechanical extensions of man. Some machines are designed by teams of engineering specialists, each with a limited sphere of responsibility, and in such cases it is easy to overlook their overall function of serving Man. The classic example is perhaps a fighter aircraft which was designed by the usual teams of specialists. The resulting product was a fine technical achievement, somewhat marred, however, by the inability of pilots of normal stature to get into the cockpit!

This particular example is from the U.S.A., but similar cases are by no means unknown in British industry. At a recent examination of a proposed design no fault could be found with the engineering design as such, but candour compelled the observation that one difficulty did remain. This was to design and manufacture the entirely new kind of human being who would be required to operate the proposed machine. It was fortunate that the consultation was made in time and the proposed idea was discarded. The essential difference between the two countries does not lie in current practice or malpractice. It is that the Americans are taking drastic steps to remedy such situations whereas we, unfortunately, are not.

Habitual "Sets" in Thinking.—A further main cause of neglect is the blinding effects of habit and custom. This applies to experimental psychologists as to others, of course, but they are perhaps a little more aware of, and on guard against, its effects. They are newcomers to industry and this can be a definite advantage, in this connection. One example of its effects is found in the design and layout of typewriter keyboards. Studies were carried out to test new layouts. The general idea was to place the letters most frequently used under the strongest fingers and relegate others to the weaker. The arrangement, which is optimal, depends upon the structure of the particular language in use, which must first be analysed to find the relative frequency of letters (varying, of course, between different languages). The studies showed the large improvements which usually follow this kind of investigation.

But it is possibly more important that further inquiry was made to find why such an ineffective design had been adopted in the first case. The account given by one reputable source is that the typewriter was originally designed by an ex-compositor. He took over the arrangement of printers' blocks with which he was familiar. This layout dated back to the Middle Ages. The story goes that the arrangement, although ineffective for printing English, was excellent for printing Latin, and this had been its initial purpose!

The Designer/User Aspect.—A further reason for the neglect of the operator's skills is perhaps the most important, and is the most easily remedied without specialised knowledge. The designers of machines do not usually have to use them for any extended period. An example of the effects is seen in the wide difference in comfort, convenience and safety between a commercial lorry and a private car. The fact that car designers usually drive cars, while lorry designers do not habitually drive lorries, probably goes far to explain the difference. It can scarcely be doubted that the designers of many domestic appliances, cooking stoves and the like, are blessed with remarkably tolerant wives. It is difficult to believe that they have ever used their own products.

Subjective Factors.—Human beings are sometimes used ineffectively for a variety of associated reasons for which it is difficult to find a generic term. The neglect may stem from the typical human reluctance to take outside advice, or to submit a problem to independent investigation if this involves the surrender of any vestige of authority. In the extreme cases this tendency may terminate in the well-known disease of "N.I.H." (Not Invented Here), by no means unknown in British industry. Some years ago work was carried out on the direction indicators of cars. At that time the flashing light turning indicators were not legal here, and our semaphore arm type was not accepted in several other countries. It is clearly an economic advantage to produce standard cars, which can be exported without detailed modifications, to all countries. It therefore seemed useful to make controlled comparisons of the different signals. A long series of tests was carried out, using human reaction

times, mistaken responses, relative visibility, and the time to learn the meaning of the signals as the experimental criteria. The studies gave clearcut results on their relative merits, and it was possible to point to the main faults of each type and to suggest improvements. There was, therefore, real hope that the issue of legalising flashing indicators would be decided on the basis of measured data rather than opinion.

The status of scientific behaviour studies at that time is well illustrated by the fact that amended regulations soon followed the report. But so far as was possible, they were directly opposed to its recommendations on every major point. The result is that good, bad and indifferent car signals of many different kinds now appear on our roads. The resulting increase in confusion and uncertainty is causing the public concern and outcry which could have been reliably foreseen from the early experiments. The British public is in the unenviable position of repeating them on a larger scale and with much greater danger to life and limb. Industry and civil authorities, like the Armed Services before them, are learning the lesson the hard way, that it pays to have measured data of human performance. But there can be no doubt that the scientific method will ultimately replace individual hunches and opinions in this field, as it already has in the physical sciences.

Restrictions of Investigation.—A final reason for the comparatively ineffective use of people and their skills is the taboos and restraints which limit certain lines of investigations, because of their highly emotional content. The subject of human engineering in the main is comparatively innocuous. This is not the case when certain extensions of the methods and findings are suggested. These extensions would carry the work into the field of social engineering, which is concerned with the relations, and methods of communication between people, rather than between machines and people. It is widely alleged that such investigations would be harmful, because of the existing tensions within industry.

Some recent experiments on repetition-work machines will serve as an example. One group of test workers were given machines which had a counter indicator in clear view. They therefore had continuous and rapid information on the number of items they had produced. Another group was given no numerical information of this kind. No bonus or incentive payments were given to either group ; the experimental variable was simply the giving or withholding of plain information. The group who had information or knowledge of results gave consistently higher output of the order of 25 per cent, and this obtained when the groups were changed round to equate the factor of ability.

The Future of Human Engineering

The skills of the future will be determined in part by developments in human engineering. There are still many obstacles, already discussed, but there is no real doubt that the findings will play an increasing part, and conceivably in the very near future.

The work in presenting information and of arranging optimal methods of control and display to link man and his machines or work space will undoubtedly continue. But the problems of the transfer of skill are probably of far greater immediate importance in view of the need to re-employ an ageing population and the redeployment of workers as automation develops.

The immediate problems of training or re-training fall under three main headings. The first is the simplest, because a great deal is already known about it and the methods are direct. The problem is to design machines so that the habitual skills of everyday life show the highest possible transfer to their use. This will by itself reduce learning time, increase the number of people who can learn, and reduce the risk of accidents when the operators are under stress. A simple example is that the frequent use of domestic taps develops the expectation that anti-clockwise motion will increase water flow, and conversely. But many steam valves and other devices use exactly the opposite convention. This convention certainly increases learning times, but there is no known evidence concerning the effects on accidents in these particular cases.

There is such evidence, however, with more complex examples. Control levers of the joystick type are often used to control machines which move in two dimensions. Two different conventions are possible to relate (*a*) the direction of joystick movement to (*b*) the resulting movement of the machine. The machine may move in the same direction as hand movement, and this convention makes full use of the habitual skills of moving an object with the hand, pointing at a moving object, writing, and other everyday skills. But this convention is not favoured by many engineers. They argue that a joystick is usually a lever pivoted in the middle and, considered in this way, it is natural to point the far end of the lever in the direction in which the machine should travel. This then entails the opposite convention, that machine movement is the reverse of hand movement. This argument has now raged for many years and is entirely analogous to the controversy about the horse's teeth, since it is so much easier to find out than to argue. It therefore seemed useful to set up experiments to decide the matter, and these were carried out about ten years ago. The clearcut answer was that the convention which may seem natural to engineers who understand a machine's construction is highly unnatural to the average operator who lacks this background. His learning time is greatly increased and he may well make mistakes under stress, if a given direction of limb movement leads to opposite motion of the machine. This inefficient and unnatural relationship is still widely produced, however, and used in various public services who have certainly received the reports. Apparently the learning aspect still seems unimportant to many engineers. But in personal experience there have been serious and tragic consequences when men have been transferred at short notice between machines which use different conventions. Machines with different and opposed relationships of this kind are widely found in close proximity, and this is far more dangerous than standardising either.

The classical example is perhaps a mechanised trolley used for coal transport underground. The machine cannot be turned around underground in the confined space, so the simplest system is to provide seats facing opposite ways and pivot the steering wheel so that it can be positioned appropriately for either direction of travel when the driver changes seats. But the result is that the directional conventions used in steering are directly opposed on the journey to, as compared with from, the pithead and, moreover, the positions of the brake and accelerator pedals relative to the driver's feet are completely reversed. Such arrangements are, without doubt, as criminal as designing a car without brakes and, apart from slightly reduced costs, have nothing to commend them.

A second problem in the transfer of skill arises in the use of synthetic training devices, which are widely used in the Armed Services. A particular use is for the preliminary training of aircraft pilots, but they are in very general use whenever initial practice on the real machine is precluded because of time, cost or risk. They are also used to teach emergency and similar procedures for which the real machine is unsuitable, or to give the occasional practice which is needed to retain high skill in some activities. Devices of this kind could undoubtedly be used far more widely and effectively in industry and other spheres. The current and barbarous practice of allowing car drivers to learn from scratch on congested and dangerous roads is one case from many.

It would be a real social service, and probably a lucrative one, to find how much initial skill could be gained from preliminary practice on a synthetic trainer in the quiet and safety of a room. Again, crane driving and other potentially dangerous skills might well be taught initially on such synthetic trainers.

There are formidable problems, however, in determining precisely what the operator is learning, his critical difficulties, and how best to simulate them with maximum economy. Current technique in designing such trainers is to make them as nearly like the real machine as possible. This can be a most wasteful procedure with expensive machines, and for a number of abstruse psychological reasons (which need not detain us) it is not necessarily the best method for obtaining high positive transfer. A number of comparative studies have been made. Cases have been found where very expensive simulators with high "face-validity" were, in fact, far less effective than much cheaper devices which concentrated exclusively on the critical point of difficulty. This occurred despite a complete lack of resemblance to the real machine.

The point was well brought out in recent studies of training aids for a machine which has rapidly-acting acceleration controls. Preliminary and frequent refresher training was required, and the real machine was too difficult, dangerous and expensive to allow direct practice. But the requirements were satisfactorily met by training the operator in balancing a steel ball in the middle of a plate.

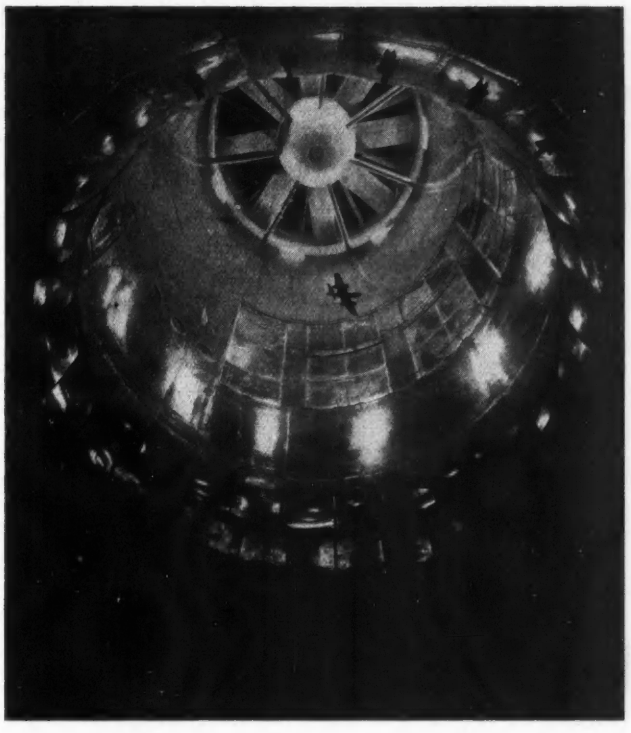
Synthetic trainers are the same in principle as the "predesign" simulators already discussed. The problem is to present critical control difficulties as economically as possible. The latter's functions are different, however, since their main purpose is to try out projected engineering solutions and to optimise system parameters before a prototype machine is actually made. They are particularly valuable when new control problems are likely to arise, for example, in designing new high-speed aircraft. The alternative procedure is to design the machine in the light of previous experience, which may be a dubious guide, when unknown man/machine factors are involved. This procedure ends in inviting an intrepid test pilot to find out whether a human being can actually control the machine. The answer that he cannot may lead to considerable wastage in finance and in far more valuable lives.

It would be idle to pretend that ready-made solutions are available for such problems at the present time. But the future will demand that they be found from much closer collaboration of physical and biological scientists than is the present case. Such problems clearly merit research and support on a national basis.

Opening of the R.A.E., Bedford

No. I

On Thursday last week, the Minister of Supply opened the Royal Aircraft Establishment, Bedford, originally known as the National Aeronautical Establishment. It comprises principally large wind tunnel facilities, together with a gas turbine power station to drive them, and an extensive flying field having much special equipment, and being able to represent carrier landings and launches. Some of the displays and installations are described here, beginning with an account of the flying and static displays on the opening day.



PARTICULARLY interesting features of the opening day were a static display at the aerodrome, and a flying display in which no less than one-third of this country's supersonic aircraft took part. The aerodrome is used by the flight division of Aerodynamics Department, by the Blind Landing Experimental Unit, and by the Naval Air Department, and the demonstrations of each will be described in turn.

Aerodynamic Flight Research.—Making its first public appearance since the S.B.A.C. flying display the year before last was the English Electric P.1.A., which has come to Bedford for a detailed investigation of longitudinal stability and control. This will involve measurement of tailplane loads, which are to be determined by strain gauging of the aircraft structure near the tail mounting. Since this part of the structure is subject to thermal strain, a temperature survey is being carried out as a preliminary, and an additional heat shield has been incorporated. It is interesting to note that the " Sapphire " version has fixed area nozzles, with shallow inserts at the orifice for minor adjustments to the area, and that the after burners are installed well forward in the jet pipes, there being a flame holder with a very large area circular gutter close up to the fuel nozzles. An interesting detail is that the brake parachute is stowed below the fuselage, but streamed from the base of the fin ; its trace therefore takes the form of a pair of wire cables which run round the trailing edges of the rearmost fuselage panels, behind the air brakes, in a manner reminiscent of radial engine cowling retainers. While the general appearance of the P.1.A. is now well known, it may be worth while to give some account of the detail execution of the aircraft. The primary structure is principally light alloy, flush riveted ; the use of special fasteners shows the presence of integral fuel tanks inboard of the undercarriage bays and behind the leading edge. The leading edge has a radius of the order of an inch, and on the aircraft displayed the " sawcut " to improve the flow over the tips had been narrowed to about one-half by insertions. The base or end of the cut is rounded in longitudinal section, but not solid, there being a narrow spanwise slot along the region of the stagnation point. The flaps are constant chord on the trailing edge, short and tapered on the leading edge ; the ailerons have mass balances at inner and outer ends, and fit very closely.

The gun ports of this machine had been blanked off, and no strictly military equipment was provided. On the " A " machines the cockpit is deep within the profile of the fuselage, and the one-piece hood was hinged at the centre, opening back and up ; it clearly would not resist jettisoning. It is normally retained by two hooks each side engaging latches in the fuselage. Within the cockpit there are individual throttle controls and an on-off reheat selector. The belly fuel tank is carried well back, overlapping the forward engine access panels ; there appear to be no power or instrumentation connections to it, and it is presumably emptied by air pressure, The tail surfaces comprise the all-moving stabiliser, which has some semblance of a fairing at its root, and a fin and rudder, of which the former appears to have an insulated tip and the latter is excellently shrouded.

The main undercarriage legs pivot about axes inclined to the horizontal in order to bring the wheel into the plane of the wing ; the retracting jack gains leverage by having purchase on both the leg and the breaking strut. The brakes are hydraulic on two coplanar discs, shallowness being, of course, imperative. An attractive detail is an external indicator to warn the ground crews that the pilot used the emergency circuit to extend the undercarriage. Other details also make it clear that the machine was not regarded as a research aircraft to operate solely from specially equipped aerodromes ; for instance, a special key is required to open access panels in the wings and rear fuselage, and stowage for it is provided in the fuselage. The aircraft took off after running some distance with the nosewheel high in the air ; the main wheels retracted sharply, followed slowly by the forward-lifting nose wheel. A restrained display was given, apparently without the use of after-burning, though the engines were seen to smoke slightly on increasing power after a dive. The parachute was streamed on landing.

The other supersonic aircraft flown was a Fairey " Delta 2." The " Avon " after-burner, in contrast to that of the " Sapphire," had a slender flame holder, principally of three spokes outside and six inside a circular gutter, set well back from the nozzles and little distant from the variable nozzle. Opposite the flame holder a corrugated radiation shield protected the jet pipe. The delta remained in the air for twenty-three minutes and landed without using a parachute.

Another delta to take part was the Boulton Paul P.111 ; this was flown with slightly truncated wing tips, having also tips which give a fully triangular plan or truncation almost as far as the ailerons. This aircraft has recently been used to investigate inertia coupling between roll and pitch, which clearly will be accentuated in a machine of low aspect ratio and low lift curve scope ; it is of interest largely because of the high angles of attack anticipated in flight at great altitudes.

In the static display there was seen a Hawker " Hunter," which had been modified to approach slightly closer to the dictates of the " area rule " at Mach 1. Fairings had been added to the sides of the fuselage from just forward of the centre section trailing edge aft ; they were wider and shallower than those often seen on United States aircraft, and hence inconspicuous. The drag of the aircraft was found to be reduced at transonic speeds, although the fuselage volume and surface area were increased. No adverse effects on stability or other characteristics were found. The same aircraft is now being used to develop a technique of visualising shock waves in flight ; the principle is illustrated in Fig. 5, and the light source is the sun. A camera is mounted above the wing near semi-span, with a mirror to direct it either outboard or inboard, and two alidades are erected to show the direction of the sun. Another technique is to smear a viscous silicone oil on the surface ; ripples are expected on the oil under the detached boundary layer aft of the shock, but not upstream of it. Another " Hunter " was the subject of an experiment to measure the pitching moment of inertia, being supported at the two wing jacking points on " knife edges " of $^1/_{10}$in radius and at the nose on coil springs of known stiffness. From measurement of the frequency of oscillation and knowledge of the c.g. position (previously measured) the inertia is deduced.

Another experiment intended to yield information essential to the design of automatic control systems had been carried out on a Gloster " Meteor " VII two-seater. Vertical accelerometers had been installed at the c.g., the tail, and in each wing, and apparatus provided to sense incidence and elevator angle. Simultaneous records of all were made directly on paper. In flight, an arbitrary fore-and-aft stick movement was made, ending at the trimmed condition. The harmonic content of the elevator movement and the frequency response of the aircraft were then derived from the records in a reasonable time by a digital computer, and the pitching derivatives of the aircraft can be elicited from these relations and the phase

8FT BY 8FT SUPERSONIC WIND TUNNEL AT BEDFORD

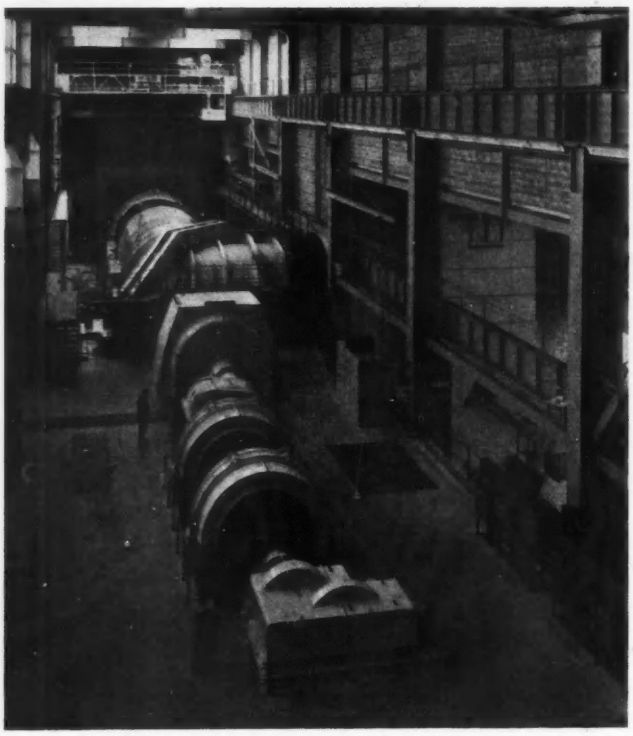


Fig. 1—Compressor house : next to the compressor is the 68,000 h.p. a.c. motor, then come the speed increasing gears and two d.c. motors of 6000 h.p. each. In the foreground is the large gearbox for the barring motor, working in the opposite sense to the other gearbox

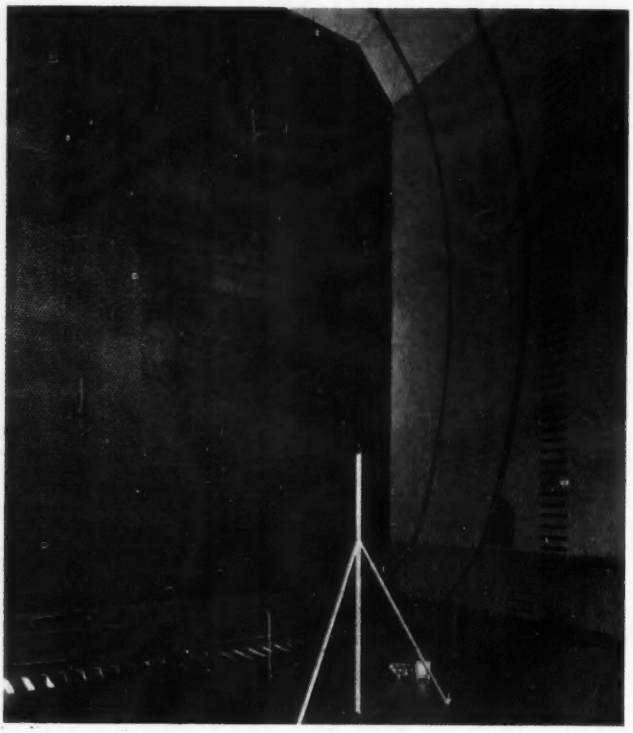


Fig. 2—Downstream face of the cooler: the flat walls seen are within the pressure shell, the 58,000 tubes forming a square that extends beyond the corner fillets. Electric-resistance-welded tubes, expanded and welded into the tube plates, are used

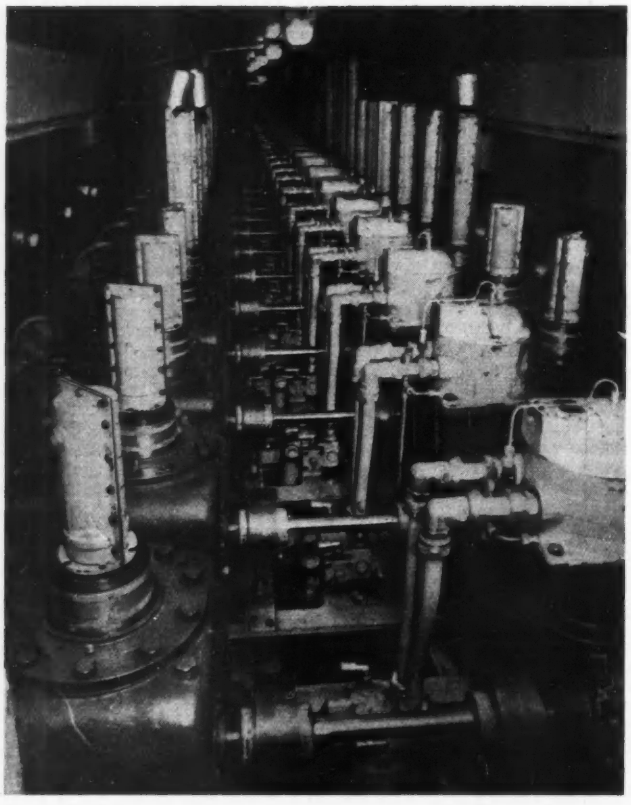


Fig. 3—The jacking stations of the upper nozzle wall: at each station a hydraulic motor mounted on a worm gearbox drives two screw jacks. Notice the oil baths on the lead screws, and the provision for grease gun lubrication

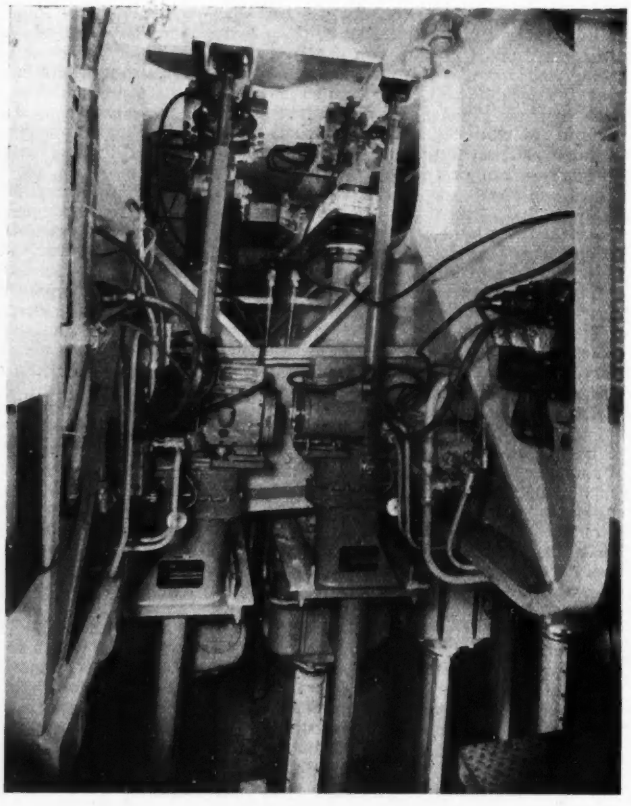


Fig. 4—Two of the pilot screw units on the lower wall of the nozzle. Beyond them can be seen the ends of the lead screws, bearing upon arcuate attachments to the stiffeners welded to the flexible plate : the effective centre is on the neutral axis of the plate

angles. While this technique has only been applied to longitudinal stability, it is believed that analysis of directional and lateral responses can also be programmed ; it is pointed out that the flying time involved is remarkably short. The stability of the " Meteor " is also involved in a series of trials carried out on a Mark IX, intended to discover how little longitudinal damping is acceptable to the pilot. The aircraft, which already has an autostabiliser on the rudder to suppress the snaking that made gunlaying difficult, has had one added to the elevator, but working in the reverse sense to reduce stability. A third " Meteor " was in use for the development of flight test instrumentation.

Also shown were aircraft with blown flaps and deflected jets, the Rolls-Royce " Flying Bedstead," and the Short S.B.5, complete with spare aft fuselage with high-set tail.

Blind Landing Experimental Unit.—The Blind Landing Experimental Unit moved to Bedford from Martlesham Heath in April, 1957. The main runway has been equipped for blind landing experiments, although these mean landing the opposite direction to other aircraft when easterly winds prevail. The unit has developed a radio altimeter, which was demonstrated by an exceedingly precise low pass at very low speed by a Vickers " Varsity," while a downwind touch-and-go landing by an English Electric " Canberra " testified to the adequacy of the runway.

While approach couplers have already been achieved, the pilot is still required to maintain the correct airspeed in the approach, and the difficulty of controlling the aircraft near to the minimum power speed leads to approaches being made at speeds higher than ideal. To obviate this limitation an automatic precision control of airspeed is under development ; sensing units with an output capable of driving such a system already exist, and the Youngman device for this purpose was described on page 457, March 22, 1957.

Naval Air Department.—The Naval Air Department is charged with maintaining compatibility between aircraft and aircraft carriers. One of its products on display, the deck-landing mirror sight, is already a standard fitting in R.N. and U.S.N. carriers. There has been built on the aerodrome a steam catapult, covered by an imitation deck, 5ft above ground level, and another is being installed at ground level to investigate operation at much higher steam pressures (the steam catapult was described on page 127, January 28, 1955). A demonstration was given of the catapult in operation, the piston being dragged back down the deck by a wheeled tractor, and the aircraft taxied into position, steered through a tiller attached to the nose wheel leg by a deck crew member. The hold-back took the form of a wedge attached to the aircraft, clamped between two halves of a cylinder surrounded by a metal ring, the thrust at which the wedge pulled clear being set by the tensile strength of the ring ; a simple spring-loaded catch located the ring in the correct axial position. The other end of the hold-back engaged a shoe on the deck. A de Havilland " Sea Vixen " and a Hawker " Sea Hawk " were catapulted, the latter also showing off its powered wing fold. The " Sea Hawk " gave a particularly impressive exposition of controllability and piloting skill when it was landed on the arrester gear incorporated in the naval runway ; the aircraft was flown straight and level inches above the ground until the hook engaged the arrester wires and the " water squeezer " brought the aircraft to rest. A favourable wind allowed this use to be made of the arrester ; in most cases the ground speed at landing would be greatly in excess of that on a carrier, so that the aircraft is merely taxied into the arrester ; if it does not engage the pilot either stops within or takes off from the remaining 1300 yards of runway.

Carriers without angled decks made use of barriers to catch overshooting aircraft. This application is now of less interest than that of saving an aircraft running out of runway, and the department is developing barriers for land use. The aerodrome barrier being merely an emergency safeguard, and needed on perhaps six runways, capital cost is of great importance, and an interesting proposal is to use drawn nylon ropes for a low net across the runway end and undrawn nylon ropes to anchor that net ; the undrawn nylon would yield plastically to the impact of the aircraft, absorbing about 35,000ft-lb per pound of nylon. A model display demonstrated this technique ; a full-scale experiment in which a " Meteor " taxied slowly into a net, with the engines at or near full power, resulted in the barrier being penetrated. Since such nets are, in any case, useless to swept-wing aircraft, development has now turned to arresting the main undercarriage legs, a technique which has been shown in the United States to be less damaging to the machine.

Other devices projected by the department are a system of power-driven rollers to position aircraft on the steam catapult without the delay involved in accurate taxi-ing, a jet blast deflector to protect aircraft waiting behind the catapult, and a device to retrieve the catapult launching bridle, as is already practised on U.S.N. carriers.

The heading picture is a photograph of the vertical spinning tunnel with the lower catch net and the rubber foam mattresses on the walls not installed. A model " Meteor " VIII has been hung in the tunnel to represent the mode of operation. Conspicuous are the eight-blade fan and the ring of twenty-seven adjustable flaps ending the by-pass duct that provides a higher energy flow immediately within the walls. On the opening day the fan was dismantled, and there were displayed dynamic models of the Saro " S.R.53 " and Gloster " Javelin," which were used while the tunnel was out of commission. They were dropped from a balloon at 4000ft, time clocks operating the flying controls and finally releasing a parachute. To obtain a reasonable Reynolds number these models were larger than those for the pressurised tunnel, which latter are up to 3ft span.

8ft by 8ft Supersonic Tunnel

The largest tunnel at Bedford, in terms of circuit length, is the 8ft by 8ft supersonic tunnel, the circuit centre line forming a rectangle 350ft by 60ft. It offers Mach numbers up to 2·8 at a stagnation temperature of 40 deg. Cent., and stagnation pressure can be varied from 0·1 to 4 atmospheres absolute. The " cold " leg of the tunnel commences with the cooler, the section here being 47ft diameter, and a settling section, followed by a 16 : 1 contraction into the rectangular nozzle, the side walls of which are plane and parallel. This part of the tunnel is contained within a circular section pressure shell, and continues with the working section and the supersonic diffuser, which has the side walls adjustable. The subsonic diffuser transforms the tunnel section to a circle, and leads to two corners with turning vanes. The " hot " leg commences with the compressor, the first four stages of which are followed by vanes supporting an intermediate bearing, the remaining six stages being replaceable by an annular section for running at low pressure ratios ; the tunnel here has its minimum diameter of 20ft. The circuit expands gradually through two more vaned corners to the cooler.

Tunnel Structure.—The tunnel is claimed to be the largest pressure vessel in Europe, and contains about 5000 tons of steel ; its structural design, fabrication and erection were carried out by Whessoe, Ltd.

The tunnel circuit is broken down into a number of sections, each of which consists of several plate courses. These sections were erected with their axes vertical on top of temporary plinths, and when welding of the seams had been completed they were lifted by a derrick, rotated, placed in their final position in the tunnel circuit, lined up and fastened by cleats before the final circumferential weld was made to the adjacent shell.

For this heavy lifting a large steam derrick was used. This had a 175ft long boom, a 200ft mast held by ten guy ropes, and was capable of precise inching movements in hoisting, luffing and slewing. It enabled lifts of the order of 80 tons at 80ft radius to be carried out and the heaviest lift was 130 tons at 30ft radius from the mast centre. Positions for the derrick had to be chosen carefully in the early planning stages of the work and the four positions chosen initially proved to be sufficient for the complete job.

The steel plates used for the tunnel structure vary in thickness from $\frac{3}{8}$in to $1\frac{3}{8}$in, but there are a number of complex openings which require reinforcing plates up to $2\frac{1}{2}$in thick. For parts of the pressure shell $\frac{13}{16}$in thick and above, " Coltuf " was used, the remainder being boiler quality steel to B.S.S. 14.

The pressure shell is rigidly anchored to the foundations at the compressor, the cooler, and the two corners upstream of the compressor. Elsewhere it is carried on supports which allow freedom of movement in one or more directions ; a redundant structure of this nature was illustrated last week. Changes in longitudinal length of the shell between anchor points are absorbed in five expansion joints ; the maximum movement to be accommodated is of the order of 5in and the minimum $\frac{1}{4}$in. The joints handling the smaller movement are of the bellows pattern ; sleeve type joints, sealed from leakage by inflated rubber seals, are used for the larger movements, and one compressed rubber joint is used.

Protective coating of the pressure shell varies with the operating temperature range. An aluminium metal spray and silicone-based aluminium paint were used on the outside of the hot leg. The cold leg, downstream of the cooler, outside, was finished with a standard grey enamel paint over a red lead primer. The whole of the inside of the tunnel was given a cold phosphate etch and two coats of a protective paint.

The whole structure was fabricated on site to Lloyd's Class I standards for pressure vessels, except that stress relieving of the complete vessel was not carried out as it was considered to be impracticable and Class II routine mechanical tests were used in place of Class I tests, which were considered to be extravagant and unnecessary. Thus, all pressure-resisting welds—just less than a total of 16,000ft—were X-rayed to a sensitivity of about 1 per cent or, in areas inaccessible to X-rays, gamma-rayed to a sensitivity of about 2 per cent. The total defective welding was as low as 4 per cent of the total footage welded.

To take into account the departure from Class I code, the nominal design stress was reduced from 13,900 lb per square inch for ideal Class I construction, to 11,800 lb per square inch. This was for the 28/32-ton u.t.s. " Coltuf." For the boiler quality steel, 26/30 tons u.t.s., the design figure was 10,950 lb per square inch.

Hydraulic tests of the tunnel pressure shell were carried out in three sections as construction of each section was completed, the open ends of each section being blanked off with hemispherical ends. The application of the test pressure was in three stages, 55 lb, 65 lb and 75 lb per square inch absolute at the horizontal centre line of the tunnel, each pressure being maintained for thirty minutes, followed by a return to zero (static head) to enable strain gauge readings to be taken. All points where high stresses were expected were covered by plumber's resin and/or strain gauges. A final examination for water-tightness was carried out at 75 lb per square inch absolute with satisfactory results, but inspection of the resin showed some slight cracking of welds on the radial weld stiffeners at Nos. 3 and 4 corners. It was decided that this was mainly due to locked-up weld stresses, and the cracks were subsequently satisfactorily repaired.

Fig. 5—Visualisation of shock waves in flight by natural light

All tunnel supports and foundations were designed to accommodate the weight of the water, but ties were used across the expansion joints so that the overturning moments for which certain foundations were designed should be those due to the operating pressure and not the hydraulic test pressure.

Finally, an air pressure test was carried out on the complete structure with all expansion joints free to move. The air test pressure was 1·1 times

working pressure. Records were taken of the movements of expansion joints and foundations and the pressure shell examined for signs of leakage. Apart from the h.p. and l.p. compressor sections which had not been hydraulically tested, the structure was found to be sound and tight. Repairs subsequently carried out to reduce the leakage at the compressor proved successful.

Working Section and Supersonic Diffuser.—The working section nozzle, which is contained within the 30ft diameter pressure shell of the tunnel, consists of two side walls which are fixed

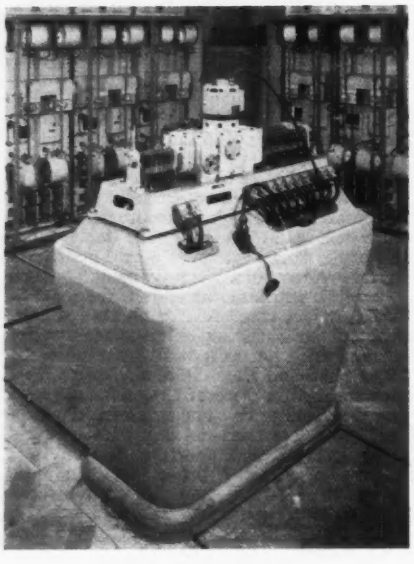


Fig. 6—The motor-driven cam-contact pulsator that provides impulses at 6·5 per second for the tape readers seen in the background

and top and bottom walls which can be flexed to form a convergent/divergent nozzle.

Each flexible plate forming the top or bottom wall of the nozzle is made from two "Ducol" plates butt-welded together and machined to give finished dimensions of 64ft 8·438in ±0·060in long by 7ft 11·875+0·000−0·020in wide by 1in thick over 52ft of its length from the downstream end, decreasing in 0·070in steps to a thickness of 0·65in. The airswept surfaces are finally coated with "Araldite"; the coating of the plates was carried out on site in a specially constructed oven 68ft long by 9ft wide by 4ft high, incorporating seventy 2½kW tubular heating elements to provide the heat for curing the "Araldite" after spraying. The oven was erected between crane rails in a movable shed which could be rolled clear of the oven to enable a travelling crane to lift the plates.

Across the back of each flexible plate are welded thirty-one T-shaped stiffeners, and to each stiffener (except the first, which is the upstream attachment point) are attached two 3½in diameter by 2 t.p.i. screw jacks which are used to support and flex the plates; the jack attachments on to the stiffeners are roller race sectors designed so that their effective pivot point is the neutral axis of the plate.

The forces involved are large, the jacks being able to carry 30 tons compression and 15 tons tension, while the displacements involved are closely specified, there being 14,000 different contours which are separated at the most by 2ft 11in. The jacks are driven by gearboxes giving a reduction of 25 : 1, and each pair of jacks is driven from an 18·5 : 1 worm gear by a hydraulic motor on the latter gearbox: the sixty jacks on the upper side of the nozzle are seen in Fig. 3. The control system for these jacks is, naturally in view of the complicated requirement they have to meet, highly elaborate. Each hydraulic motor is connected to a 650 lb supply through a sensitive valve, and this valve is displaced by any axial movement of a nut in a pilot screw jack; thus, if the main jacks are not set to correspond with the length of the pilot jacks, they move toward this condition. (A pilot jack assembly is seen in Fig. 4.) The pilot jacks have four t.p.i., or eight near the end of the nozzle where Mach numbers are higher, and each is advanced in discrete steps by an electric motor; individual impulses correspond to 0·0025in or 0·00125in. The required throat geometries are stored on a punched tape system, there being one reader for each of the thirty stations. Of the five available perforations on the tape, the first two are used for the upper and lower jacks, allowing a slightly asymmetrical input if such is found to be desirable, and the second pair command negative jack movements because in some cases certain of the jacks move in the opposite direction to the remainder. The remaining perforation is used on eight of the tapes which control the supersonic diffuser. The entire set of readers respond in unison to the demands of a pulsator, seen in Fig. 6: the tapes move in opposite directions for increasing and decreasing Mach number, so that reversible tape readers are required. Supervision of the electrical control system is provided by installing a pair of tape readers, with identical tapes, for each jacking station: one drives the impulse receiving unit on the pilot jack, the other a monitor in the control room. Both receiving unit and monitor operate contacts by means of cams, and if the two fail to move in unison an alarm circuit stops the control system. Circuits are provided for diagnosing faults and injecting impulses to annul the resultant discrepancy. Supervision of the mechanical equipment is provided by curvature gauges on the back of the flexible plates near each stiffener; these give continuous indication of the stresses in the plate and stop the movement if a safe stress is exceeded. This safeguard service is itself automatically checked on every change of Mach number. The control system was proved by constructing a single prototype jacking station at Bedford, which was subsequently used for life tests; experience on this rig led to the thread form of the main jacks being changed from square to a modified Browne and Sharpe and the material of the nuts from cast iron to leaded bronze. The electrical system was the work of the General Electric Company, Ltd., the hydraulics of Costain-John Brown, Ltd., and the mechanical gear of Opperman Gears, Ltd.

The model may weigh up to 1 ton and is mounted on a sting supported on a gear quadrant which is housed in a 15in wide centre fairing in the supersonic diffuser, downstream of the working section. The quadrant is driven by two hydraulic motors through an arc of ±22·5 deg. to enable the angle of incidence of the model to be varied over that range, and the movement is controlled by coarse/fine magslips to an accuracy of ±0·025 deg. In a similar system the angle of roll of the model can be varied over a range of ±180 deg. with an accuracy of ±0·125 deg. A model is seen in Fig. 7.

The hydraulic servo system used to control these movements is similar to that for the working section with the impulse receiving unit replaced by a magslip. Additional equipment is provided for aerodynamic calibration of the tunnel; the model support sting can be replaced by a calibration probe which has an electro-hydraulically controlled axial travel of 8ft.

A battery-operated trolley is used to bring the model complete with sting from the rigging room through the main tunnel access door, which is a flanged elliptical opening 9ft 5¼in by 7ft 5¼in., into the supersonic diffuser. The trolley is equipped with hydraulic rams for raising and lowering the model and with five manual adjustments so that the model and sting can be offered up to and mounted in the sting housing.

The model is viewed indirectly through a periscope system and by a closed circuit television system; there is also a schlieren light system, which displays the air flow pattern round the model. The pressure distribution over the surfaces of the model is measured by orifices connected to manometers; strain gauges measure the stresses in the model (all these readings are automatically recorded) and a six-element balance has been provided to calibrate the strain gauges and to separate the lift, drag and side forces and the pitching, rolling and yawing moments.

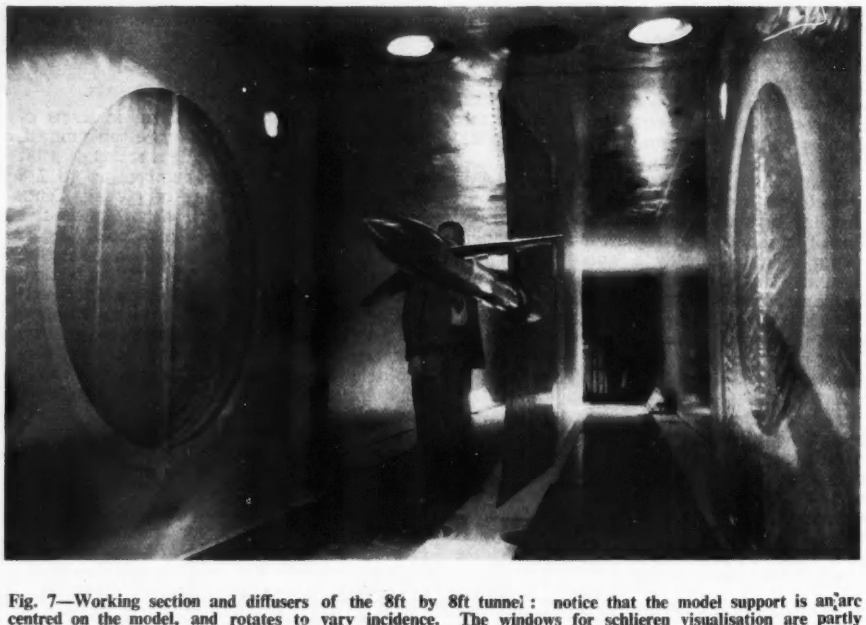


Fig. 7—Working section and diffusers of the 8ft by 8ft tunnel: notice that the model support is an arc centred on the model, and rotates to vary incidence. The windows for schlieren visualisation are partly obscured by transparent curtains to protect them from visitors. The model is large enough to accept movable control surfaces

The pressure distribution along the air-swept surfaces of the contraction, working section and supersonic diffuser is displayed in the observation room. This manometer installation required over 40,000ft of ⅛in diameter copper tubing.

A total of 137 twenty-two-core cables for working section and supersonic diffuser controls and instrumentation have been taken through the pressure shell, in addition to manometer tubing for instrumentation and Pyrotenax cable for power and lighting circuits. The copper manometer tubing and Pyrotenax cable pass through the tunnel shell in copper sleeves, which are brazed into Monel metal plates bolted on to bosses on the tunnel shell. Seven Monel plates each 10½in diameter by ½in thick are used, five for manometer tubes and two for cables. Each of the former has thirty-seven ½in diameter copper tubes for the 185 manometer tubes and the cable plates have twelve copper tubes of various sizes to suit the different cable sizes. To prevent air leaks the cable sheath or manometer tubing is soft soldered to the copper sleeves.

The supersonic diffuser is 59ft 3in long and

consists of fixed top and bottom walls, connected by side frames into a rigid structure, and moving side walls. The side walls each consist of five sections, the longest of which is 25ft long and the shortest 5ft long, hinged together and moved by screw jacks. The screw jacks are driven by hydraulic motors in a manner similar to the flexible plate jacks with a magslip system replacing the impulse receiving units and monitors. The control is from the additional holes punched in six of the eight above mentioned control tapes, enabling the diffuser walls to be automatically set to the desired position for a particular Mach number. For the supersonic diffuser there are three jacking stations, each of two jacks, for each side wall, the maximum movement of each jack being 2ft 6in in steps 0·05in at a maximum rate of 1·8in per minute.

At the third hinge of the diffuser, downstream of the 25ft section, adjustable injector slots are provided, driven by two more jacks and controlled by the remaining two tapes. While the main diffuser walls are driven through double worm reductions of 290 : 1, these are driven by single-stage 70 : 1 units. All jacks have 6in diameter, 1in pitch Acme threads, and take 75 tons tension and 5 tons compression. An emergency push-button enables the by-pass doors to be opened at full speed if compressor surging is anticipated.

The diffuser is 8ft square at the upstream end which joins the working section and diverges to 10ft 4in square at the downstream end which leads into a subsonic diffuser.

The tunnel structure can be split at circumferential bolted flanges at each end of the supersonic diffuser, and the whole structure weighing approximately 800 tons, and which is carried on a thirty-two-wheel truck, can be moved out of stream and parked so that it may be replaced by another diffuser section.

(To be continued)

Royal Show at Norwich

This week, the Royal Agricultural Society of England is holding its annual show at Norwich. It opened on Tuesday and closes this (Friday) evening. The "Royal" is one of the annual occasions for a comprehensive display of all kinds of agricultural machinery and allied equipment. This year there are fewer new machines than at most of the other post-war shows, but there are many examples of the development work of agricultural engineers. Here we give a general survey of the machinery section of the show.

THIS year's Royal Show, which is being held this week on a well-appointed site at Costessey, Norwich, has all the characteristics of those which have preceded it in the post-war years. The last occasion on which the show was staged in East Anglia was in 1951 at Cambridge ; it is therefore appropriate that Norwich—a city set in the midst of a large agricultural area—should have been selected for this year's "Royal." H.R.H. the Duke of Edinburgh is honouring the Royal Agricultural Society by serving as president this year, and one significant event of the week has been a conference of Royal Agricultural Societies of the Commonwealth. Since 1839, the year in which it was founded, the Royal Agricultural Society of England has been active in encouraging "practice with science" in agriculture. Through the years, the Society has assisted, in numerous ways, the development of agricultural machinery and implements. Although the Society's competitive trials of machinery are no longer held annually, those which it does organise at intervals continue to be of great value to that large section of the engineering industry which is concerned with the design and manufacture of agricultural machines and implements.

A large acreage of the extensive show ground at Norwich is taken up with the products of engineers. The 600 stands occupied by machinery makers display examples of all the equipment that is essential to the highly skilled business of farming. That display presents excellent evidence of the work that engineers continue to perform in order to assist the world's agriculture. This year, there are fewer items of new equipment, but many of the exhibits indicate ways in which the versatility of existing machines and implements is being increased. It is interesting to compare the machinery exhibits at this year's show with those at the "Royal" when it last took place at Norwich in 1911. On that occasion, there were 457 exhibitors of machinery and implements, and steam traction and portable engines had a prominent place. But we reported that "quite the most noteworthy feature of the heavy engineering section is the increasing numbers of firms which are showing tractors propelled by internal combustion engines." Petrol and paraffin-engined tractors, principally in the 30 h.p. to 50 h.p. range, were exhibited by British firms in 1911 ; they bore little resemblance to their successors. Comment about the likelihood of internal combustion engine power replacing steam power in cultivating the land was restrained. We, for example, felt bound to say about the Norwich Show of 1911 that "the display of heavy agricultural tractors propelled by internal combustion engines using paraffin and petrol as fuel was quite worthy of the best traditions of the Royal Agricultural Society, and it was extremely satisfactory to note that all the examples of this branch of engineering were purely of British origin. Although the Society's ploughing trials, last autumn, demonstrated pretty conclusively that steam haulage was much superior for agricultural work as regards cost so far as this country is concerned, it must not be lost sight of that there are countries where water of any description is far too scarce to use for steam-raising purposes, and if not too scarce is quite unsuited for steam boilers. Solid fuel is also frequently too expensive on account of the cost of transport. In such countries the paraffin or petrol engine can and will take the place of the steam engine and boiler."

Fig. 1—Small crawler tractor fitted with two-stroke diesel engine giving 8¼ h.p. at 2300 r.p.m.

Before many years had passed, however, the internal combustion engine had succeeded steam power for agriculture. For a long time, it is true, the farm tractor was not much more than a "draught horse." But for several years now, the tractor has come more and more to be looked upon as a farmer's mobile power house. The numerous items of tractor-operated, as well as tractor-drawn, equipment shown at Norwich this week emphasise that fact very strongly. Recent tractor development has been concerned principally with greater engine efficiency and the extended use of hydraulics. Examples of most of the wheeled and crawler tractors produced in this country are exhibited at the show, and one of them, the "Ferguson 35," introduced last autumn by Massey-Harris-Ferguson, Ltd. (see THE ENGINEER, October 5, 1956), was entered for the Royal Agricultural Society's silver medal award for new implements.

Among the many smaller tractors at the "Royal," there is another new version of the "MG 6" (Fig. 1), which is manufactured by Ransomes, Sims and Jefferies, Ltd., Ipswich. This tractor, which is fitted with tracks, has a Drayton diesel engine developing 8¼ h.p. at 2300 r.p.m. It is a two-stroke, single-cylinder, air-cooled engine with overhead exhaust valve, which is, incidentally, interchangeable with the petrol or vaporising oil engines installed in these tractors. No modification to the chassis is needed if it is desired to change to the diesel engine.

Materials Handling

The progressive mechanisation of agriculture has meant, of course, a steady reduction of the tasks done by hand. But, until comparatively recently, not very much attention has been given

Fig. 2—Tractor-drawn hay baler. The machine is powered by a 12 h.p. twin-cylinder engine

to the subject of materials handling on the farm. In all kinds of farming, the moving of materials can take up a lot of time and labour ; there is now an increasing amount of equipment available which can be said to come within the scope of materials handling. Several manufacturers are exhibiting this kind of equipment at Norwich. A good example of handling farm material mechanically is illustrated at the head of page 23.

This illustration shows a front-end loader working in co-operation with a muck spreader, both of which machines, together with the tractors by which they are operated, being among the exhibits of International Harvester Company of Great Britain, Ltd., 259, City Road, London, E.C.1. The steel channel basic frame of the loader, it will be noted, " hugs " the natural line of the tractor closely enough not to be a hindrance when it is required to operate other implements ; the loader arms can be attached by locating four pins in the basic frame and lift rams. The maximum lift is 10ft 6in and the lifting capacity is 1500 lb. The loader illustrated is fitted with a seven-tined fork, but there is also a 10 cubic foot capacity bucket available. The farmyard manure spreader shown in the illustration is operated by the tractor's power take-off. The apron of this machine has seventeen bars, eight of which are in contact with the load at all times to maintain a steady feed to the forged steel beater at the rear end. The action of this beater shreds the material, which is spread by a balanced spiral situated at the extreme end of the machine. A universal-jointed shaft enables the machine to be quickly attached to the tractor p.t.o. and a shaft running the whole length of the machine gives smooth transmission of power to the driving mechanism. A ratchet slip clutch, held in engagement by a tension spring, is incorporated in the main drive so that there is adequate protection should the apron, beater or spiral become jammed. The same firm is exhibiting a 3-ton capacity, hydraulic tipping trailer which is suitable for use in conjunction with the front-end loader mentioned above.

A new 3-ton hydraulic tipping trailer is shown on the stand of Ford Motor Company, Ltd., Dagenham, Essex. It is one of a number of joint products of Ford and Ransomes, Sims and Jefferies, Ltd. This trailer has a steel channel chassis with a box-section hitch beam, a 10ft by 6ft hardwood body which is tongued and grooved with steel support members, and a loading height of 33in. The sides and tailboard of the trailer are hinged. The trailer hydraulics include a two stage ram giving a tipping angle of about 50 deg. The trailer has been designed for use with tractors equipped with the automatic pick-up hitch, but it can be coupled to tractors without this attachment. Hand-operated internal expanding brakes are part of the trailer's standard equipment.

Balers for dealing with hay and straw can appropriately be considered as materials handling equipment. A new baler at the show is the " 703 " produced by Massey-Harris-Ferguson, Ltd., Coventry ; it is a machine which has been designed to meet the requirements of smaller farms. The pick-up mechanism is placed close to the axle so that the pick-up fingers follow closely the changing ground contours. Bale lengths can be varied between 20in and 40in. The baler (Fig. 2) is powered by a 12 h.p. air-cooled twin cylinder J.A.P. engine ; there is another model available driven by the tractor power take-off. On this latter model of the baler, there is an over-running clutch to protect the tractor when slowing down or changing gear.

A fork lift for attachment to the Ferguson tractor is another " materials handling " exhibit on the stand of Massey-Harris-Ferguson, Ltd. The lift is hydraulically controlled by two levers which operate self-neutralising, two-way valves ; it can lift a 10 cwt load to a height of 10ft 9in.

Tractor-Operated Implements

On the stand occupied jointly by Marshall, Sons and Co., Ltd., and John Fowler and Co. (Leeds), Ltd., the exhibits include a heavy-duty tool bar for the 50 b.h.p. " Track-Marshall " tractor. The tool bar (Fig. 3) can carry implements such as subsoilers, heavy cultivators and trenchers ; it is 9ft long and of 4½in by 7½in section. Raising and lowering of the tool bar is effected by a centrally mounted double-acting ram, the hydraulic pump being driven through the camshaft gear so that live hydraulic power is provided independent of the main engine clutch. The hydraulic system of the " Track-Marshall " operates at a maximum pressure of 1500 lb per square inch.

An example of " spinner broadcasters " for lime or fertilisers is illustrated by Fig. 4. This particular machine is a recent product of Massey-Harris-Ferguson, Ltd., and can be attached either to a tractor or a trailer. The drive for the broadcasting mechanism is taken from the pneumatic-tyred landwheels through bevel gearing, in which a free wheel is incorporated. The drawbar, incorporating a clevis hitch, is adjustable for height from 11½in to 17½in.

There is, as usual, a big selection of grass mowers exhibited at the " Royal." A newcomer is a Massey-Harris-Ferguson mid-mounted mower driven by the tractor power take-off through a transmission shaft and pitman. Cutter bars of 5ft or 6ft can be fitted, there being a spring and plunger safety release mechanism to give protection against obstructions. A cable assembly depresses the clutch pedal when the safety mechanism is released so that the tractor

Fig. 4—Spinner broadcaster for fertiliser, the drive for which is taken from the landwheels

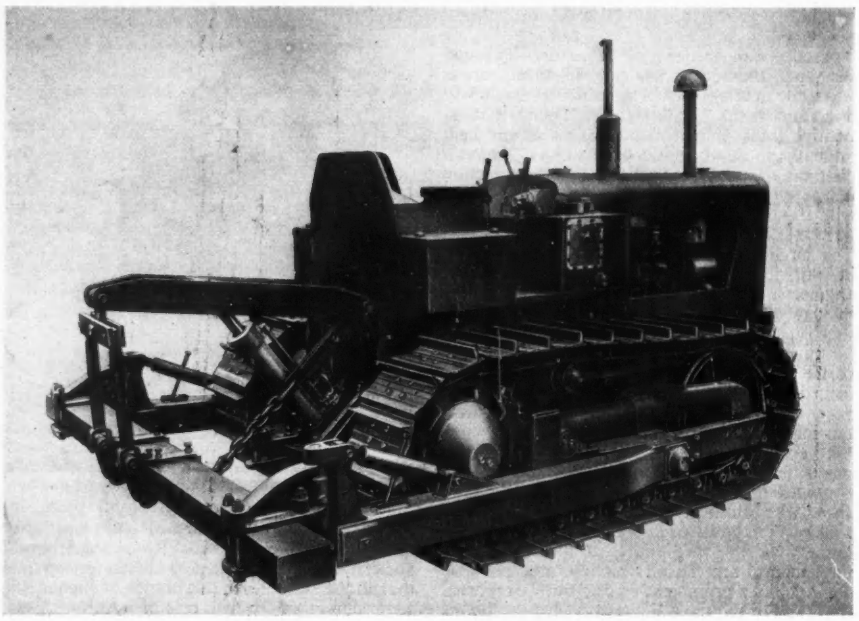


Fig. 3—50 b.h.p. diesel crawler tractor fitted with hydraulically-operated toolbar

is stopped automatically. There are two versions of this new mower, giving, respectively, 1077 and 848 knife reciprocations a minute.

In an article on last year's Royal Show (THE ENGINEER, June 29, 1956) we referred to the Wilder-Rainthorpe chopper which is made by John Wilder, Ltd., Wallingford. The machine, which is driven from the power take-off of a tractor, is for chopping straw (left in the field by a combine harvester), or clearing potato haulm and similar material. It can also deal effectively with undergrowth found in woodlands and similar places. There is a rotor which carries two rows of fast moving flexibly mounted chopping blades which carry the material between two rows of fixed knives ; the material is thereby bruised and cut prior to being dispersed by deflector plates incorporated in the machine. This year, John Wilder, Ltd., has introduced a further version of this machine to enable it to deal with grass for silage making. For this purpose, specially designed tines are fitted to the rotor. A deflector shield, made from fibre glass, is fitted to assist the conveyance of the chopped material to a trailer which is towed along behind the machine.

OIL ENGINES

Diesel fuel injection equipment and electrical equipment for tractors and for stationary and portable engines are to be seen at the show. An interesting exhibit in this class has been arranged by C.A.V., Ltd., Acton, London, W.3. It consists of two working models illustrating the operating principles of a diesel engine and of its fuel injection system. The sequence of operations is indicated by a series of descriptive panels which light up as the models rotate.

The manufacturers of the various oil engines suitable for agricultural work are well represented. One of them, Petters, Ltd., Staines, Middlesex, includes in its exhibit examples of its " PC " high-speed diesels which were described in our issue of June 14. This firm has been making a collection of its vintage engines and nine of them are displayed on its stand. The oldest of them is a 1¾ h.p. single-cylinder engine, dated 1893, which was used for driving pumps, root pulpers and similar machines. Another of these historical exhibits is a 3 h.p. motor-car engine, made in 1895, which, it is claimed, was fitted in the first all-British car.

ELECTRICITY IN AGRICULTURE

The British Electrical Development Association has collaborated with the Eastern Electricity Board in staging an " Electricity Farm " which occupies about 18,000 square feet of space in the educational section of the Royal Show. This exhibit includes standard farm buildings in which there is demonstrated electrical equipment used in dairying, poultry husbandry and pig keeping. Electrical equipment used for cattle and poultry food processing machines is also shown. In addition, there are examples of electrically operated grain and grass dryers, while the horticultural section of the exhibit demonstrates methods of electrical heating and soil warming, and the use of such items as soil shredders and sterilisers.

Several items of electrical equipment are shown on manufacturers' stands. The British Thomson-Houston Company, Ltd., Rugby, is exhibiting fractional horsepower motors suitable for driving equipment like butter churns and milk coolers. Another B.T.H. exhibit is the " Stayrite " a.c. single-phase power drive, which is available in sizes of 2 h.p., 3 h.p., and 5 h.p. This power drive consists of two components—the motor and its associated starting unit. It is designed as a composite equipment for use on farms where easy installation and reliability are essentials. The motor is a foot-mounted machine having a good starting torque with a low starting current. The starting current is only 1·5 times the normal full-load current ; the 2 h.p. and 3 h.p. motors develop 75 per cent full-load torque at starting and the 5 h.p. unit develops 60 per cent. The equipment can be supplied with either a hand-operated air-break starter or one of the automatic push-button contactor type. The " Stayrite " equipments are suitable for use on 230/240V, 50 cycles, single-phase circuits.

SILVER MEDAL AWARDS

Every year, the Royal Agricultural Society awards silver medals for new implements or machines which have been satisfactorily tested in actual practice. The awards are decided by a panel of judges. This year there were forty-four entries for silver medals, and twelve of them were accepted for judging. Silver medals have been awarded by the Society as follows :—Kennett Handling Equipment, Ltd., for a handling system involving containers to suit all kinds of farm materials ; E. C. Longmate, Ltd., for an " archway " spray boom ; Massey-Harris-Ferguson, Ltd., for a land speed power take-off as arranged in the Ferguson " 35 " tractor, and Wolseley Engineering, Ltd., for the " Super Swipe " rotary cutter and pulveriser.

Earlier this year, it may be recalled, the Royal Agricultural Society carried out some competitive trials of ditch cleaning machines. Fourteen machines, large and small, took part in this competition ; for two of the machines, silver medals were awarded by the Society, and bronze medals were awarded in respect of five others. All the machines which participated in the trials (THE ENGINEER, May 17, 1957) are exhibited at the show this week. A few weeks ago, the Society stated that it now proposes to organise a competition for the design and production of kale harvesters. This competition will most likely be held in 1959.

British Transport Commission's Report

IN the ninth annual report and statement of accounts of the British Transport Commission for the year ended December 31, 1956, which has just been published, the accounts are framed in accordance with the new basis of accounting embodied in the Transport (Railway Finances) Act, 1957. Under this Act the Commission's accumulated deficit up to the end of 1955 plus the deficit on British Railways for 1956, are transferred to a special account which holds in suspense for subsequent amortisation the extra costs and deficits for the period of modernisation, reorganisation and development.

The accounts show that the Commission's working surplus for 1956 was £4,500,000 before charging interest on capital, capital redemption and certain special but minor items. When the year's deficit on British Railways—totalling £16,500,000 loss in working plus £41,000,000 interest and other charges—is transferred to the statutory Special Account, a net surplus for the year of £3,100,000 remains. This represents the balance of profits and losses made by various parts of the undertaking other than British Railways, after deducting their appropriate share of interest and other charges. The results are generally in line with those forecast and published in the White Paper, " Proposals for the Railways," issued in October last and in which the Commission considered that, subject to certain assumptions, its annual net revenue should be in balance by 1961 or 1962 ; and that by 1970 there would be a surplus of £50,000,000 a year over and above the cost of servicing the capital.

The amount to be borrowed under the Transport (Railway Finances) Act, 1957, in respect of the year 1956 is £54,400,000, i.e. the transfer to the Special Account (£57,500,000) less the surplus of other activities (£3,100,000). The amount so borrowed is roughly one-fifth of the total sum envisaged by Parliament as necessary (£250 million), and broadly in accordance with the expectation when the financial plan was announced.

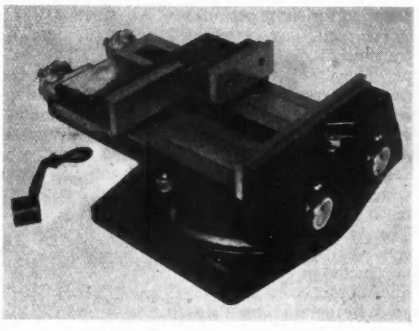
In making a comparison of the working surplus for 1956 (£4,500,000) with that of 1955 (£26,600,000) the Commission attributes the deterioration to three main factors : the decline in freight carryings by both road and rail (at least some of which is explained by the continued growth of " C " licence vehicles and by the further disposal of B.R.S. vehicles), and the decline in the carryings of London Transport ; the freezing of the Commission's fares and charges in an attempt to assist in combating inflation ; and the continuation of inflation, though in a less acute form. Emphasis is also laid upon the problem which faces the provider of public transport by the continued growth in numbers of other vehicles on the road. The report points out that in fulfilling its obligation to provide services as specified in the Transport Act, 1953, the Commission shoulders a large measure of social obligation and performs the more onerous tasks of public transport, including the carrying of peak traffics, but the greater the congestion of road traffic, the more expensive it becomes to provide public transport, particularly for passengers, without which the great majority of those who travel at regular times would not be transported at all. A downward trend of London Transport's traffic in 1956 is in part ascribed to the steadily worsening congestion in Central London, which cannot fail to make public transport less attractive and reliable.

The progress which has been made in the modernisation and re-equipment of the railways and the settlement of their finances on a realistic basis is considered of particular importance by the Commission. It is pointed out that, although it will possibly take a decade or more to overcome the effect of several decades of underinvestment and to revolutionise the national railway system, results began to materialise in 1956. During the year large orders were placed for new equipment, passenger miles constituted a record for the period since the Commission took over and diesel trains imparted a new stimulus to travel in many areas.

Machine Vice

A HEAVY-DUTY vice with 12in opening, 12in wide jaws, which has been added to the " Hylo " range distributed by Alfred Herbert, Ltd., Coventry, is illustrated herewith. This vice has two 2½in deep, 6in wide jaws actuated by an automatic differential, two-speed mechanism.

The jaw lead screws are cut with a two threads per inch modified square thread and a ten threads per inch thread. When a jaw is being adjusted the shaft moves it at the rate of ½in per revolution until it contacts the workpiece. This contact load automatically brings the other screw pitch into effect to advance the jaw at $^{1}/_{10}$in per revolution. When a vice is bolted on the bed of a machine in such a position that the handles cannot be fully revolved, a finger grip handwheel fitted to each shaft provides means of rapid positioning of the moving jaw prior to gripping. Thereafter, full grip and release is obtainable without removing the handle from the shaft.



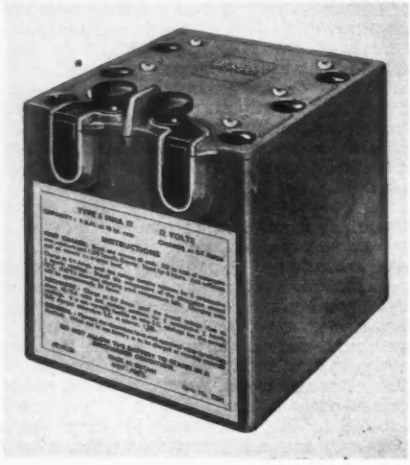
Heavy-duty machine vice with two independent 6in wide sliding jaws

The two-speed device is fully automatic and operates at any point between fully open and closed. The mechanism is completely enclosed and readily removable filler plates in progressive lengths are provided to protect each lead screw from swarf or chippings.

Lightweight Low-Loss Batteries

Two new lightweight batteries, designed to combine low open-circuit losses with "unspillability" have recently been introduced by Chloride Batteries, Ltd., Exide Works, Swinton, Manchester. They are known as the 6MNA17 and 4MNB17 batteries, and the capacity is 4Ah at 12V and 8V respectively.

Basically the two batteries are of similar design, but their applications differ. The 12V battery, illustrated here, is primarily designed to



This 12V battery has a capacity of 4Ah, is housed in a polystyrene case measuring 3·9in by 4·8in by 4·25in high, and weighs about 4¾ lb filled and charged

operate portable and airborne v.h.f. equipment and other special electronic devices, while the 8V battery is intended for valve-operated electronic apparatus. The unusual nominal voltage of 8V is planned to meet the demand for batteries required to work with 6·3V valves, where designers specify that the terminal voltage shall not fall below 6V. This condition is difficult to obtain with a 6V battery, but an 8V unit with a small ballast resistor gives a satisfactorily flat discharge curve down to an end voltage of 6V. The 4MNB17 battery is also designed to work efficiently with "transistorised" circuits, and both batteries are intended for applications where high-rate discharges are required for short periods.

The cells are assembled in containers of translucent high-impact polystyrene. The battery covers are one-piece mouldings of the same material, obviating the need for individual cell lids. They are cemented to the containers by a process which is claimed to ensure a reliable and leakproof joint.

Gas vents, incorporating traps for acid spray, are positioned in the covers and each cell has a separate filler plug. The possibility of the cell vents becoming obstructed or blocked by dirt is practically eliminated by positioning the acid traps and vents in the cover rather than the filling plugs. The battery tops are therefore almost flat, which enables a more efficient design of acid trap to be used.

Inter-cell, inter-row and end terminal connections are made by passing lead alloy connectors through leakproof joints in the cell walls. External connections are insulated against accidental short circuits by polythene covers and protected from damage by raised shields on the container moulding. This kind of inter-cell connection reduces the weight of the battery and, by minimising the length of the conducting path, ensures that the battery can maintain a high terminal voltage during high-rate discharges.

Within each cell positive and negative plates are separated by sheets of the microporous plastic material "Porvic." The separators are wrapped around the positive plates, enclosing both sides and one edge of the plate to eliminate the possibility of short circuits between the edges of positive and negative plates. The 6MNA17 battery also has sheets of resin-bonded glass wool against the positive plates as protection from the effects of vibration frequently encountered in service. The use of dry inert separators of "Porvic" enables the battery to be stored indefinitely, under suitable conditions, in a dry unfilled state.

The terminals, on top of the battery, are not directly connected to the end cell take-offs. Each consists of a "Monel" metal insert moulded in the battery cover, into which is screwed a small "Monel" metal bolt with an insulated head. When this bolt is tightened the cable end on the external lead is clamped firmly against a lead alloy strip, which passes over the edge of the battery container and is connected to the end cell take-off. A "Monel" metal washer is soldered to the contact area of the positive strip to ensure sufficient electrical contact with the cable end on the external lead, particularly at high rates of discharge, despite corrosion products which are liable to be found near the positive terminal of a battery. This offset method of terminal connection is stated to confer freedom from corrosion in service and the capacity to withstand mechanical abuse, such as severe tightening. In addition, the strain of bolting leads to the cell is transferred directly to the battery container, so that no damage is caused to the plate assembly or internal connections.

These batteries are designed to give high-rate discharges (even at low temperatures) of the order of 100A with high terminal voltages. Their "low-loss" characteristic ensures that they can be stored for extended periods between freshening charges in a filled and charged condition and always be ready for immediate use.

The 6MNA17 battery measures 3·9in wide by 4·8in long by 4·25in high, and weighs about 4¾ lb filled and charged. The 4MNB17 battery measures 3·9in wide by 3·5in long by 4·25in high and weighs about 3 lb 6 oz filled and charged.

Dumper Truck

THE dumper truck to be seen in operation in the accompanying illustration is a 5/7 cubic yard machine which is now being made by Abelson and Co. (Engineers), Ltd., Coventry Road, Birmingham, 26. It is based upon an Austin "701" chassis, reinforced by two longitudinal rolled steel channel sections which are braced by cross members and mounted on the chassis side members to ensure even load distribution. The standard range of four forward and one reverse speeds is doubled by the fitting of an Eaton two-speed rear axle. Double-acting hydraulic anti-roll shock absorbers fitted to the front and rear of the machine reduce body roll and increase stability when working over rough ground. Power-operated steering equipment has also been fitted. The vehicle was described on page 165, July 29, 1955.

The all-steel welded plate body incorporates a cab protection canopy and a scow gate rear end. A 10in radius fillet welded between the sides and the floor along the length of the body provides a reinforcement and assists in clean discharge of loads. A layer of hardwood built in between the double steel plate floor of the body reduces the effect of shocks imparted during loading.

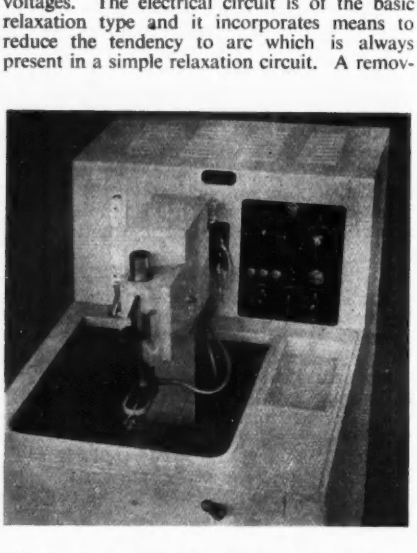
A twin underbody tipping gear is operated through three-stage telescopic hydraulic rams and tips the body up to an angle of 70 deg. Power-operated return of the body is provided through the hydraulic rams to speed the operation, and all tipping movements are controlled by a single three-way valve which imparts the raising, holding and power return motions. The hydraulic pump on one side of the chassis is driven from the engine power take-off, and is independent of the steering system.

Dumper truck with a capacity of 5 to 7 cubic yards

Spark Erosion Machine

THE spark erosion machine illustrated here was introduced recently by Rudkin and Riley, Ltd., Cyprus Road, Aylestone, Leicester. It has a 12in square work table and its spindle has a travel of 6in in the work head.

The standard machine is arranged to operate on a 400–440V, three-phase supply, but machines can be made, if required, for non-standard voltages. The electrical circuit is of the basic relaxation type and it incorporates means to reduce the tendency to arc which is always present in a simple relaxation circuit. A removable working head has a three-point support in the dielectric fluid, and the servo drive is provided by a d.c. motor and reduction unit to an arbor which carries a vee block for holding the electrodes.



Working head, table and control panel of spark erosion machine

Normally a copper electrode is used and the makers state that, although the accuracy of the work produced depends upon the shape and accuracy of the electrode, in general a tolerance of 0·002in can be easily held. The maximum cutting rate is given as about 75 cubic millimetres per minute with a standard finish suitable for most classes of work. At this cutting rate the distance between the electrode and workpiece is about 0·0025in. A vibrator, which gives a small oscillation, can be superimposed on the servo drive to assist in commencing a cut or in difficult conditions such as in deep holes.

The controls, as can be seen in the illustration, are grouped on a panel and include the pump and electrical circuit switches, a switch for the vibrator, a four-position finish switch, and a multi-stage cutting rate control. A device is also fitted to indicate instability during working.

Industrial and Labour Notes

World Economic Survey

The *World Economic Survey*, 1956, has been published during the last few days by the United Nations. It is in two main parts, the first of which deals with balance of payments problems during the post-war years, while the second examines the development of world economy last year.

Various general comments are made in an introduction to the survey. In a reference to anti-inflationary policies at present being applied by governments, it is suggested that "there is little evidence that credit restraints can provide an adequate answer to the need for expanding capacity in key industries." But in under-developed countries, the survey continues, despite the under-employment of resources, increased investment could soon become inflationary "whenever the additional incomes generated by the investment did not evoke a corresponding increase in the output of consumer goods."

The survey then points out that, in the post-war period, world demand for primary products has lagged substantially behind that for manufactures, and that there has been an important shift in world demand from consumer to capital goods. Among the primary products, it is stated, there has been considerable diversity in the growth of demand; world demand for oil has shown a steady and continuing increase, but other minerals have fared less well and staple goods and agricultural raw materials have lagged behind. It is added that, while the industrial countries have shown considerable flexibility in adapting their exports to the changing structure of world demand, "much greater difficulties have been encountered in under-developed countries." The changes in world demand and the dependence of under-developed countries on a narrow range of exports have restricted the ability of many of these countries to finance their rising demand for imports.

Industrial Production

The world economic survey mentioned in the preceding note says that economic activity continued to rise in 1956. Investment activities in industry continued to be dynamic. The pressure on resources did not appear to have increased over that of a year earlier, but the advance in prices and wages became more striking, and there was a significant rise in costs in most countries as productivity began to lag behind the rise in wages. In Western Europe the rate of increase in industrial production amounted to 4 per cent in 1956, compared with 9 per cent in 1955. In the U.S.A., however, there was only a 3 per cent rise in 1956, which was but a third of that achieved in the preceding year. Japan was a major exception; its industrial production increased by one-fifth in 1956, which was far greater than the increase attained in any other industrial country.

The investment goods industries, particularly the engineering industry, which had been working at capacity in 1955, experienced some easing of pressure in 1956. The demand for steel in Western Europe continued to increase last year, although at a slower rate than in 1955. In the U.S.A. the apparent consumption of steel was slightly lower last year than in 1955, owing to the fall in steel production that resulted from a strike last July. The survey comments that the immediate effect of the blocking of the Suez Canal and of the damage done to one of the major oil pipelines was an acute shortage of oil in most Western European countries. It also revealed the "high degree of vulnerability of one of Europe's major sources of energy." It is pointed out that a fundamental difference in Western Europe's energy situation during the post-war period compared with pre-war lies in its rapidly increasing dependence on oil, the indigenous production of which is negligible. However, the survey says, by the spring of this year it seemed clear that although the blocking of the Suez Canal had caused a number of difficulties, "the overall effect had nevertheless been much less serious than was originally feared."

Changes in Wage Rates

The Ministry of Labour reports that changes in wage rates which came into operation in the United Kingdom during May resulted in an aggregate increase of about £2,090,000 in the weekly full-time wages of 5,453,000 people. The principal increases affected workers in the engineering industry, in building and civil engineering construction, and in coal mining. Among others receiving wage increases were workers employed in railway workshops, in goods transport by road, non-skilled manual workers paid on miscellaneous "M" rates in many Government industrial establishments, and dock labourers.

In the engineering industries, it will be recalled, there were increases for men of 11s. a week for skilled grades, 10s. for intermediate grades, and 9s. for unskilled grades. Women workers received an increase of 8s. a week. In the coal-mining industry there were increases of 1s. 7d. to 2s. 2d. a shift, according to grade, for adult day-wage workers; these increases were retrospective to March 4. Workers in railway workshops received increases of 7s. to 9s. a week, according to occupation, for men, and 5s. 6d. or 6s. for women.

With the increased rates which became operative in May, the total increase in weekly wage rates in the first five months of this year was £3,160,700 for 8,263,000 workers. In the comparable period of last year, there was a net increase of £5,580,000 in the weekly full-time wage rates of 11,033,000 workers.

Employment in the London Region

A section of the report, for 1956, of the Ministry of Housing and Local Government deals with various aspects of the development plans for the London Region. In all the post-war planning of the region, it is stated, the importance of securing the dispersal of employment as well as population from the congested areas has been recognised. Unfortunately, the report says, lack of suitable statistics makes it impossible to compare changes in employment with those of population in the main subdivisions of the built-up area of London, or even to compare post-war with pre-war conditions.

The report goes on to point out that employment in the London Region is high in proportion to population. In all, 23 per cent of the population of England and Wales lives in the region and 27 per cent of the employed population works there. Between 1948 and 1955, employment in the London Region increased by about 9 per cent; that in the whole of England and Wales increased by about 6 per cent. The upward trend in the London Region was well above the national rate both in manufacturing industry and in the service trades and administration. London is therefore not only expanding as by far the greatest single centre of employment in the country, but is also increasing its share of national employment. The most marked growth since 1948, it is observed, has occurred in services and administration, and particularly in retail trade, the education and health services, insurance and banking. But the employment statistics do not differentiate between those in manufacturing industry who are actually factory operatives, and those employed in an administrative or service capacity. Thus, the staffs of the manufacturing firms which maintain London headquarters offices are included under the heading of manufacturing employment. The increase in the number of actual manufacturing operatives is therefore almost certainly less, and the number in service and administrative grades proportionately more, than the statistics suggest. Most of the regional increase in employment has occurred in the main built-up area, and during a period in which the population of that area has been falling as a result of decentralisation. In 1951, nearly a quarter of a million people travelled daily into the London Conurbation to work, but there is no comprehensive statistical evidence since the census to show whether there has been any subsequent increase in travel. The report says, however, that limited studies suggest that there has been such an increase.

It is stated that Central London contains 26 per cent of the total employment of the region and therefore presents "the greatest problems of transport and traffic congestion." It gives rise to the "major journey to work problem" with a daily influx of 1,000,000 people, over half of whom travel from beyond a 5-mile radius and over 100,000 from beyond 15 miles. The tidal flow of vehicles to and from the central area at the morning and evening peak periods causes acute congestion at many points throughout the main built-up area. These problems of congestion, the report stresses, are basically due to the concentration of too much commercial development into too small an area.

Railway Freight Charges

The British Transport Commission has announced this week that British Railways' freight charges are to be increased by 10 per cent on August 1. The reason given is increased working costs, which are expected to amount to an additional £40,000,000 in a full year. A proportion of the increased expenditure, it is stated, is accounted for by the increase of 6s. 6d. a ton in the pithead price of coal. Increases in wages and salaries and in the prices of other items such as steel, road fuel and tyres are also cited as contributory factors.

In its statement about the increase in railway freight charges, the Commission says that it has applied to the Minister of Transport and Civil Aviation for authority to increase charges for docks and inland waterways by 5 per cent. After consulting the Transport Tribunal, the Minister has approved an application for increased charges and is making a regulation accordingly.

Electrical Power in the U.S.S.R.

No. I

A delegation representing the British electricity supply industry visited the U.S.S.R. from April 16 to May 14, 1956. The party, consisting of nineteen members led by Lord Citrine, chairman of the Central Electricity Authority, visited a number of hydro-electric and thermal stations, including the experimental atomic power station, 80 miles from Moscow, controlled by the U.S.S.R. Academy of Sciences. The tour also included Noiinsk substation, an experimental d.c. installation, a load-dispatching centre, cable-making and generating plant factories, and research institutes. Some impressions of steam power station practice in Russia are given in the following résumé of part of a recently published report on the visit.

NO country has made more rapid progress in electrical development since the first world war than Russia. At the time of the revolution the U.S.S.R. had an installed generating plant capacity of about 1000MW and was producing an electrical output of about 2000 million kWh. By 1940 the output had risen to 48,000 million kWh with an installed plant capacity of 11,000MW. Between 1941 and 1945 about 5000MW of generating plant was destroyed by hostilities and in 1942, for example, the output fell to 29,000 million kWh. By 1945, however, 10,700MW of generating plant was in service, giving an output of 43,000 million kWh.

After the war the U.S.S.R. set about a vast expansion programme with the result that in ten years the electricity output was quadrupled : in 1955, by the end of the fifth five-year plan, the installed capacity was 36,900MW and the output was 170,000 million kWh. The present five-year plan envisages a plant capacity of 75,000MW with an output of 320,000 million kWh by the end of 1960. Current developments according to this five-year plan are summarised below.

Output in Millions of Kilowatt-hours

	1955	1960
Thermal stations (including peat-fired and nuclear)	147,000	261,000
Hydro-electric stations	23,000	59,000
Total	170,000	320,000

Generating Capacity in Megawatts

	1955	1960
Thermal stations	30,500	57,700
Hydro-electric stations	6,400	17,300
Total	36,900	75,000

Percentage Increases in Output

	Increase 1955–1960, per cent	Average annual increase, per cent
Sent out by thermal stations	77·5	15·5
Sent out by hydro-electric stations	156·5	31·3
Total electricity sent out	88·0	17·6

Increase in Generating Capacity

	Increase 1955–1960, per cent	Average annual increase, MW
Thermal stations	89	5,440
Hydro-electric stations	170	2,180
Total	103	7,620

Nuclear power is included in the above tables and it is proposed to build and commission nuclear power plants with a total capacity of 2000MW to 2500MW by 1960. These stations will be sited in the Moscow and Leningrad districts and in the Urals, where alternative fuels are scarce and expensive.

The pattern of consumption of electricity in the U.S.S.R. is interesting. In 1955 the Ministry of Power Stations produced 124,000 million kWh out of a total product, for the whole country, of 170,000 million kWh. The remaining 46,000 million kWh was generated in power stations operated by other ministries controlling, for example, the metallurgical industry, the chemical industry, and the automobile industry. Of the 124,000 million kWh produced by the Ministry of Power Stations, 107,800 million units (87 per cent of the total) were sold to various classes of consumers. Industry took 83,500 million kWh, transport undertakings took 3700 million kWh ; domestic, commercial and agricultural consumers shared the remaining 20,600 kWh, which represented only 19 per cent of the total sold.

District heating schemes are more common in the U.S.S.R. than in Great Britain and the combined heat and power stations that provide this service are sited near the heat load. Generally, however, the demand for electrical power greatly exceeds that for heat and this purely electrical load is met by condensing sets in power stations sited near centres of coal and peat deposits and extensive transmissions systems are required to take the power to the user, as described below.

The report of the British electricity supply delegation (which is based on visits to eight Russian power stations and a study of drawings of many others) shows that the general layout of these stations follows normal practice. The generating sets are usually arranged longitudinally, with individual control panels, in a turbine house separated by a dividing wall from the boiler-house.

At present the standard sizes of generating sets are 25MW, 50MW, 100MW and 150MW. There are thirty-five 100MW sets and two 150MW sets in service ; ten more 100MW sets and two 150MW sets are under construction. A 200MW set is being designed, a 300MW set is " being thought about," and a 500MW set is " believed to be possible." The steam conditions for the 150MW sets are 2400 lb per square inch at the turbine stop valve, with an initial temperature of 1050 deg. Fah. and reheat to 977 deg. Fah.

In the Minorov power station the sets are of 100MW and at Cherepet the sets are of 150MW. In both stations there are two boilers per set and they are operated on the block system, with interconnection in the steam and feed-heating systems and, in the case of the 150MW single reheat sets, in the reheating system as well. Initially at Cherepet there are five boilers for two sets ; the fifth boiler, at present spare, will be one of the eight boilers that will supply steam to four sets when the station is completed.

One of the interesting impressions gained by the British delegation is that the building frameworks are of much lighter design than in current British practice. It appears to be usual for boilers of Russian design to be self-supporting, but the boiler-house frame has to support an overhead travelling crane, as well as the cladding. No examples of semi-outdoor construction were seen or discussed.

Another interesting fact is that at certain Russian stations the hydrogen required for generator cooling is manufactured on site. Presumably this practice is dictated by the need for each station to be self-supporting, as far as possible, because of the great transport distances. Nevertheless, the delegation believes that it may be worth while to study the economics of manufacturing hydrogen on site under British conditions.

The use of large stretches of water with extensive surface areas for cooling in circulating water systems is novel to British eyes. Some Russian stations are sited near small rivers or stations with restricted flow in certain seasons. Ponds are formed by barrages built across these rivers and the intake and outlet channels (usually concrete culverts) for the cooling water are separated as widely as possible. During the winter, surface cooling is aided by the natural cold, and the dry air conditions.

Steam Turbines

Nearly one-third of all the thermal plant in the U.S.S.R. is used to generate electricity and supply process or heating steam, and large frame machines running at 3000 r.p.m. have been developed. For district heating schemes in which the heating medium is water, single pass-out machines, bled at 17·5 lb per square inch, are used. In steam distribution schemes 100lb per square inch is standard. For supplies to large chemical works and steel mills double extraction machines passing out at 100 and 280/350 lb per square inch, are installed. Most of these machines are built on the 50MW single-flow condensing turbine frame and give outputs up to 35MW under pass-out conditions. The last low-pressure group of blading is smaller because of the reduced amount of steam to the condenser.

Normally, the 50MW and 100MW non-reheat turbines are designed for stop valve steam conditions of 1250 lb per square inch and 1000 deg. Fah. The 100MW, 150MW and 200MW reheat turbines are designed for pressures of 1800, 2000 or 2400 lb per square inch, with temperatures of 1000 deg. Fah. at 1800 lb per square inch or 1050 deg. Fah. at 2000 or 2040 lb per square inch.

The high-pressure cylinders are provided with inner casings which limit both the pressure and temperature to which the outer casings are subjected. The 150MW sets already in service, and built for 2400 lb per square inch and 1050 deg. Fah. stop valve conditions, have been provided with an austenitic section in the inner casing. This practice will not be repeated, as up to 1060 deg. Fah. the whole of the turbine cylinder will be constructed of suitable ferritic steels. Carrier rings are used in intermediate-pressure cylinders. Lower pressure casings are fabricated from steel plate heavily reinforced with support bars, ribs and a stiff horizontal flange, the fixed diaphragms being supported in separate carrier rings fitted in the outer casing. The high-pressure rotor is manufactured with discs integral with the shaft (mono-block construction). The same construction is used for the first-row wheel and following seven single-row stages of the intermediate-pressure rotor, whilst the larger low-pressure blading is carried on shrunk-on discs.

In the 150MW unit all the diaphragms in the high-pressure cylinder casing, together with eight in the intermediate-pressure cylinder casing, are built up from high-grade steel. The last three diaphragms of the intermediate-pressure cylinder and the three diaphragms in each flow of the double-flow low-pressure casing are cast-in stainless iron plates. These cast diaphragms appear to be made from a hard white cast iron mixture containing little or no free graphite or silica ; they should therefore not be subject to " growth " in service.

The high-pressure glands of this large machine comprise nine separate sections having a combined axial length greater than that occupied by the cylinder blading, and care has been taken in the design to prevent shaft distortion due to temperature differences between gland sleeve and spindle and also by accidental rubbing in the event of vibration. It was suggested to the designer that a central admission high-pressure casing would permit of this high-pressure spindle being placed in almost perfect thermal balance. He appeared, however, to fear accidental rubbing in the centrally located diaphragms separating the initial flow from the reheat flow sections of the blading. This is difficult to understand for, as was pointed out, the gland sections could be separated and a leak-off provided to the condenser.

As each flow of the double flow 150MW set low-pressure turbine contains only one normal stage before the divided exhaust stage—and guide vanes are necessary to introduce steam to this first stage—it may be that comparatively unstable flow exists throughout this double-flow blading. The proposed inclusion of two extra stages in each of the double flows of the 200MW machine should materially improve the blading efficiency of this low-pressure section.

It was noticed that the rotating blading in all high and intermediate-pressure cylinders is of extremely heavy bulbous section, and that the heavy shrouding is secured to the blade by means of a very robust rivet of circular section machined on the tip of each blade. In addition, very free use is made of brazed-in lacing wires through the

intermediate and low-pressure blade path, presumably to guard against blade vibration in these stages.

On machines of up to 100MW capacity the centrifugal speed governor operates indirectly on the master relay, associated with a powerful thrustor through intermediate levers, linkages and pilot relays. For the 150MW and larger output capacity reheat machines, a newly-developed modulated sensitive oil governing system has been evolved. All intermediate levers, links and pilots arranged between the governor and a master relay have been eliminated. A very sensitive centrifugal speed governor now gives motion to a pressure leak-off pilot which revolves in the bore of the master relay ; this motion is given to the leak-off pilot by a rotating leaf spring which distorts in a known manner with change of speed. The leak-off pilot has a definite position for each governor speed and this results in a definite pressure to the modulated sensitive oil governor system. In this new system even the friction of a governor sleeve has been eliminated.

Two emergency governors are provided on all frames and act directly on the stop and emergency valves of the set. Pass-out valves on extraction machines, or interceptor valves on reheat machines, have their power-operated oil cylinders adjacent to but not over the steam valve stems, a neat follow-up linkage of robust construction being employed.

Designs have now been completed for 200MW alternators with stator and rotor inner cooling for delivery from the works by the end of this year. For these alternators the electrical rotor diameter will be 44½in and the length of the stator core 18ft 4½in. Investigations into the design of a 300MW alternator with liquid cooling applied to the stator are in hand.

Inspection of the works showed that good quality work is being produced. Of particular interest are two machines developed at Electrosila works (Leningrad) for the taping of alternator conductor bars, including the involute coils at each end. These machines are said to be the only ones of their kind in the world. They apply tape at a uniform tension over the whole of the conductor. Each machine is such that it requires a considerable through-put of conductors of exactly the same size and shape in order to justify the method, and has obvious advantages where many alternators of the same rating are being produced.

Boiler Plant

Up to the time of the visit, the largest boilers manufactured in the U.S.S.R. appear to be about 530k lb per hour evaporative capacity. These may be either of the once-through type, or of the drum type, for pressures and temperatures up to 2400 lb per square inch and 1050 deg. Fah. In these circumstances the 150MW reheat turbine is provided with two boilers per set, but preliminary designs are now being evolved for a 1540k lb per hour unit boiler for the 200MW set. At the moment attention is being concentrated on a drum type of boiler which will operate satisfactorily at 2400 lb per square inch without assisted circulation. Research and experiment is being carried on to evolve the design of a suitable once-through boiler of 1540–1875k lb per hour evaporative capacity, for operation at either 2800 lb per square inch or, alternatively, in the neighbourhood of 3500 lb per square inch. The U.S.S.R. can call on over twenty years' experience in the construction and operation of once-through boilers in excess of 440k lb per hour capacity and in this field they have a valuable contribution to make.

The boiler plant associated with the 150MW turbine set at Cherepet is of particular interest as, owing to the low-grade coals consumed, a very large combustion chamber is necessary, the horizontal dimensions being about 35ft by 23ft for a 530k lb per hour unit. In spite of the tall furnace employed, the discharge temperature of the gases is 2100 deg. Fah. and is only chilled to 2020 deg. Fah. by the water screen before entry to the convective section of the superheater. To achieve even this temperature of 2100 deg. Fah. a radiant first-stage superheater is located in the top and roof of the furnace and absorbs about 85 B.Th.U. per pound of working substance, or nearly 21 per cent of total heat required for superheating. Immediately following the first convective section of the pendant superheater another 130 B.Th.U. per pound or, roughly 32 per cent, is absorbed, and in the second convective section of the pendant superheater a further 192 B.Th.U. per pound, or 47 per cent of the total heat of superheating, is finally taken up to raise the temperature to 1050 deg. Fah.

A pendant reheater is incorporated after the superheater at the top of the boiler and downcomer chamber. This pendant reheat bank adds 205 B.Th.U. per pound of working fluid to increase the temperature of the reheated steam from 650 deg. to 977 deg. Fah. The gas temperature in excess of the working fluid temperature is therefore about the same in the secondary section of the main superheater as in the reheater—a practice which makes economical use of steel in the heating surface design.

Every endeavour has been made in the construction of boiler plant to conserve the use of steel. The boilers are self-supporting, so that the supporting stanchions will expand a moderate amount in the vertical direction, with rising temperature as against a very material downward movement of the furnace tubing. The method of securing the boiler tubes to the buck-stays must therefore be of a flexible nature, especially as all boilers inspected are brick cased and are not provided with a cavity wall to reduce heat leakage. At Cherepet each 530k lb per hour boiler furnace tube has a small rectangular plate, provided with an elliptical hole, welded to the tube. To this is attached a hook bolt, the stem of which projects through the brick casing to the anchor hole in the buck-stay. The furnace tubing had buckled considerably in service, due, it was said, to provision of an insufficient number of supporting buck-stays in a furnace nearly 100ft in height. The finish of the furnace brickwork appeared to be poor in quality. The boiler is provided with a thin sheet steel casing about $\frac{3}{16}$in thick and seal welded to the supporting steelwork to give a tidy external appearance and to check either parasitic leakage of air through the rough brickwork or blow-back of hot gases into the boiler-house.

Russian engineers have developed a method of boiler erection which involves the preparation of large sub-assemblies on site. After being moved into the boiler-house these sub-assemblies are lifted into position by overhead travelling cranes carried on the boiler-house building steelwork. At Cherepet two 30-ton cranes are employed for erection. A large site area is laid out with rail tracks, stillages, rail cranes, &c., to form an open-air workshop. The basic boiler material is delivered to site prepared for erection, but not assembled to any great degree. The whole of a boiler side wall, complete with supporting structure, buck-stays, &c., is assembled on the stillages. Sub-assembly work of this kind proceeds simultaneously on other portions of the boiler. With this system, boiler erection can begin before the boiler-house foundations and enclosing steel structure are completed and there is thus a telescoping of operations. When the lifting facilities in the boiler-house are ready final erection of the boiler commences. The sub-assemblies are moved on bogies down a central rail track into the boiler-house and hoisted into position.

At Cherepet members of the delegation were able to examine for a short time the site arrangements made for this method of assembly. Five boilers of 530k lb per hour capacity had previously been erected. The times taken for mounting the boilers with three-shift working were, for the first boiler eight months, and for boilers Nos. 2 to 5, six months each. It was stated that the programme was to erect the remaining boilers in four months each. The total weight of each boiler is estimated at 1600 tons, and of this weight 1460 tons were moved into position in about fifty sub-assemblies, some of which weighed up to 60 tons.

No weather protection was seen for the workers on site assembly. They operate under conditions which in Great Britain would not be considered favourable to good workmanship. Fans and pumps are opened up, cleaned and reassembled in the open under conditions which contrast unfavourably with the standards of cleanliness at which we aim for this class of work. It was stated that outdoor sub-assembly goes on throughout the year and that, in winter, light tarpaulin protection is erected where necessary. Welding of boiler tubes and pipework was allowed at temperatures down to −4 deg. Fah. with only tarpaulin protection. It was not possible to ascertain in the time available to the delegation whether there is any saving of man-power or man-hours in the Soviet method of boiler erection as compared with British practice, but the process is of interest and a more detailed investigation might be worth while.

Auxiliary Equipment

The connection of generators and auxiliary supplies follows conventional practice. An interesting feature of the South Urals power station was the main power connections from the generators, which crossed the forecourt of the station to the generator transformers. Each phase of the connections consisted of flexible copper overhead line conductors held by clamps in a circular formation 9in to 12in in diameter. The uppermost conductor in the clamp is replaced by a steel hawser from which the whole assembly is suspended. At each end the hawser is made-off to a string of tension insulators, whilst the conductors are made-off to their respective terminals.

The feed train layout for straight condensing plants closely follows British practice. The arrangement for the feed pump drive is interesting. The drive to each combination is provided by a single motor, flexibly coupled to a gearbox with two output shafts, one running at 3000 r.p.m. for the low-pressure pump and the second running at 6000 r.p.m. for the high-pressure pump The economy of space is quite noticable. The original intention, however, had been to mount an emergency steam turbine on a second input shaft to the gearbox, but this installation has not been made. If the steam drive is now to be abandoned it is a matter for consideration whether the method of drive will show economy over two separate motors on the same switch. With the combined gearbox drive, the freedom to select any required design speed ratio between the two pumps may have hydraulic advantages. The feed pump assembly witnessed in service ran very sweetly and was a first-class mechanical job. Gland design was good and water injection was used for sealing.

Particulars of one of the district heating pass-out units show the scope of schemes now being installed. The Moscow No. 20 station has 25MW sets, each with six bleeding points, five of these being for regenerative feed heating. Steam is bled at 17 lb to 35·5 lb per square inch for heating the water which is circulated to the district heating scheme. The heat exchangers increase the temperature of this water from 167 deg. to 250 deg. Fah., and provision is made for a live steam boost at times of heavy heat demand. The outgoing water temperature is adjusted to suit meteorological conditions. The nearest heat load is 550 yards from the station and heat is supplied over a radial distance of 4 miles. Booster pumps are provided in the return mains only. The circulating mains are laid under the streets in tunnels, which, in general, are exclusively for these mains. Progress is being made with the establishment of a heating grid on which other sections of the city system fed by various stations are to be paralleled.

Ash-Handling Plant.—Russian engineers have developed a hydraulic method, which is in widespread use, for the transport of ash to the dumping areas. Grits and ash from the furnace bottom are sluiced into a hopper from the bottom of which they are extracted by a high-pressure water ejector. The jet entrains the ash and delivers it to the disposal area. In Leningrad No. 2 station a motor-driven pump supplies 66,000 gallons of water an hour at 1000 lb per square inch to the ejector, which sets up a pressure of 85 lb per square inch in the delivery pipe. The ash is piped under the nearby tributary of the Neva to the disposal area, a distance of 3¾ miles, without the assistance of booster stations. The cast iron diffuser section needs to be renewed every few weeks. This or a similar ejector system is in use in the U.S.A. and has been offered in Great Britain. Under British economic

assessment its high-power consumption has been an insuperable handicap to further development.

Peat for Electricity Generation

Peat has been used for electricity generation for more than thirty years. In 1946, 13,000,000 tons of peat were burned in power stations ; this year it is expected that the total output will reach 55,000,000 tons, of which 25,000,000 tons will be used in power stations. It is expected that in 1960 70,000,000 tons of peat will be lifted, of which 33,000,000 tons will be used for electricity generation. Peat is used for industrial purposes either as cut or pulverised, and is compressed into briquettes for domestic fuel. The maximum economic distance for the transport of peat to generating stations was said to be 125 miles.

The total installed capacity of peat-fired stations is 1763MW. In 1955, $10{\cdot}5 \times 10^9$ units were produced from about thirty such stations (all west of the Urals), representing 12 per cent of all units generated by the thermal stations of the Ministry. The first peat-fired station, Shatura, which has now a capacity of 180MW, was started in 1925, and outside Moscow and Leningrad there are power stations with capacities ranging from 200MW to 300MW. The calorific value of the fuel varies from 4500 to 5400 B.Th.U. per pound, and as burned in the furnaces the moisture content is 40 to 50 per cent.

The most impressive feature of the technique for excavation is the completeness of the mechanisation, the size and diversity of the machines specially designed and built for the work, and the skill with which they appear to be handled. It is claimed that mechanisation has reduced the labour force from 160,000 in 1946 (for 13,000,000 tons) to 80,000 in 1956 (for 25,000,000 tons).

The first step is the digging of ditches, about 5ft wide and 5ft deep, for the removal of surplus surface water. This work is performed by caterpillar grabs, apparently of conventional design. Birch trees and shrub do not grow very tall in peat, and they are cleared by an ingenious machine consisting of a hinged vertical framework like a huge rake, with a horizontal circular saw a foot or so above ground level. This machine mows down trees and other growth in its path in wide circular sweeps. The roots are then torn out of the ground by a large pronged grab propelled by a caterpillar tractor. The larger tree trunks must be cleared by hand, after which branches, roots and scrub are swept up mechanically into the hopper of a machine, which cuts them into small pieces and scatters them over the surface of the ground. A trenching machine then cuts deep trenches, a foot wide and about 5ft deep, in order to assist drainage of the peat. The surface is then cut into rectangular blocks by a tractor-propelled machine which looks like a combination of a disc plough and a harrow, designed in such a way that the peats are turned over to assist drying. This method has now been largely superseded by what is known as the " scraper " method. This consists of tilling the peat bed like an agricultural field until the surface is broken into a fine tilth which is left to dry.

When sufficiently dry the peat is swept up by large loading cranes. If in the form of sods, the loading is done directly into trucks for transport to the generating stations. If as tilth from the surface, it is piled into large mounds for subsequent transport. The peat deposits vary in thickness from 10ft to 20ft, and it was stated that one of the cranes referred to above can clear about 37 acres in 100 days, which is the average time available per annum for peat excavation.

Still another method which is used, apparently to a lesser extent, is one in which the peat is literally washed out of the ground by powerful jets of water, the slurry being allowed to settle and the solid material is then lifted by grab for drying.

Nuclear Power

A considerable amount of economic hydro-electric development is still possible and large coalfields remain to be developed. The location of these natural resources, in relation to industrialised areas, requires a great deal of transport of energy, either as electricity or coal, as a large proportion of the population and industrial activity is concentrated in the European part of the Soviet Union. It is stated that all cheap water power resources will soon be put to use and coal mining and transportation will become more and more costly, while rapidly growing industries and agriculture will demand an ever-increasing supply of electricity and heat. In several areas, therefore, nuclear power may find immediate application and it is expected that this will be more economical than power from conventional stations in certain districts of the U.S.S.R. in Europe.

It is planned to build nuclear power stations having a total capacity of between 2000MW and 2500MW electrical output during the current five-year plan. The main programme consists of five full-scale power stations, each with an output in the region of 400MW to 600MW, although they are still regarded as being experimental. On these it is expected that experience will be accumulated in nuclear engineering and the mass production of fuel elements and their processing. The first of these experimental power stations is programmed to come into operation at the end of 1958 and the others in 1959 and 1960.

One of them is said to be based on the graphite-moderated, water-cooled reactor of the kind used at the small 5MW experimental station which was visited by the delegation. Each reactor of this kind will supply steam at about 1280 lb per square inch and 850 deg. Fah. to turbines having a capacity of 200MW, superheat apparently being obtained by passing steam back into the reactor. Two further stations will be equipped with water-moderated and cooled thermal and epithermal 200MW reactors, and 70MW turbines using saturated steam at about 425 lb per square inch.

The third type of nuclear power station will use a heterogeneous heavy-water-moderated and gas-cooled reactor, as described at the New York Conference of the National Industrial Conference Board in October, 1955. Steam will be produced at about 425 lb per square inch and 750 deg. Fah. to supply turbines of 200MW total capacity.

In addition to these large-scale nuclear power plants, it is intended to complete several smaller pilot plants by 1959, each having an electrical capacity of 50MW to 70MW. They will include :

(*a*) A boiling water thermal reactor.

(*b*) A homogeneous heavy-water-moderated thermal fast breeder reactor, using the thorium-uranium cycle.

(*c*) A graphite-moderated and sodium-cooled thermal reactor.

(*d*) A sodium-cooled fast breeder reactor, employing the uranium-plutonium cycle.

From this programme it is hoped to select the best types of nuclear power stations for future use, and to gain a great deal of information on reactor physics problems.

None of the Soviet engineers or scientists with whom discussions were held was prepared to give a strong opinion on the best type of reactor for final use in the U.S.S.R. The situation, therefore, is similar to that in Great Britain. It was pointed out that the five-year programme is specifically designed to obtain data on which such a decision can be made. Some preference has been expressed for fast neutron types based on the use of plutonium, because it is thought that world supplies of thorium are considerably less than those of uranium. For relatively short-term use, i.e. during the next ten years or so, a strong preference for the use of uranium 235 is evident, because of the lack of knowledge of the metallurgy and behaviour of plutonium. Ample supplies of uranium 235 are apparently available to meet the five-year programme. None of the Soviet engineers met was in a position to discuss the relative advantages of long-term power programmes based on plutonium or uranium 235. Discussion on the relative economic merits of different kinds of reactor was not fruitful. As this depends to a very large extent on the interest rate charged on capital investment, it is extremely difficult to get a comparison between conditions in Great Britain and conditions in the U.S.S.R., where financing arrangements are very different.

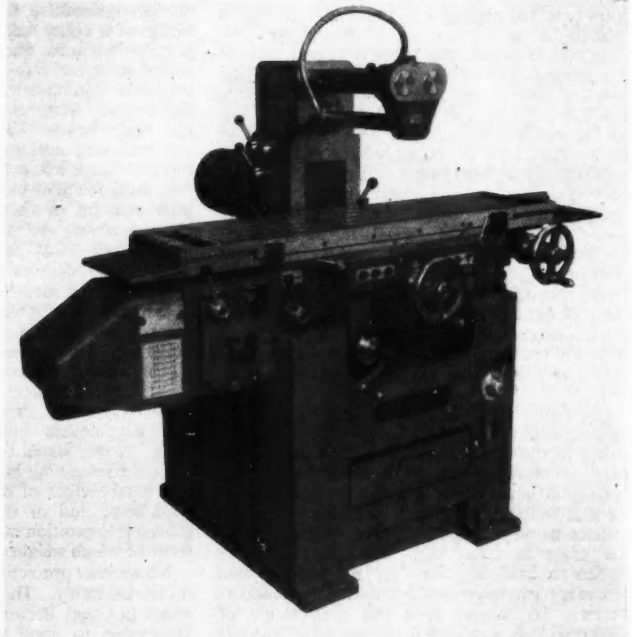
Policy on siting of nuclear power stations is not very different from that in Great Britain. At present a site must not be less than 2 miles from the nearest town. After the implementation of the present five-year programme, however, it is hoped that nuclear stations can be located very much closer to housing areas and can then be used for district heating.

Since the visit it has been reported that four of the five stations will be sited, respectively, at Moscow, Leningrad, the Urals industrial district, and near Sverdlovsk.

(*To be continued*)

Horizontal Milling Machine

We have received details of the model " Z1 " milling machine built by Société Somua, 41, Avenue Hoche, Paris (8e). As the illustration shows, it is a horizontal machine, which, however, can also be equipped with a vertical or a universal head. A slotting head, a sensitive drilling head, and a boring and surfacing attachment can also be provided. In addition, the machine can be fitted with turntable and universal dividing head. The table measures 1200mm by 300mm, and has a longitudinal travel of 710mm, a traverse of 250mm, and a vertical travel of 400mm. There are nine longitudinal and nine cross feeds, ranging from 12·5mm to 500mm per minute, and a rapid feed of 2m per minute. The vertical movement is by hand. The twelve spindle speeds range from 50 to 2500 r.p.m. for the horizontal, and from 40 to 2000 r.p.m. for the vertical spindle. The machine is powered by one 3 h.p. motor for the milling spindle and a ½ h.p. motor for the power feeds. Accuracy of the adjustable automatic stops is stated to be 0·01mm to 0·04mm, by virtue of the quick-acting brake which is fitted. The machine is handled by Service Commerciale de Vente AFMO, 63, rue de la Boétie, Paris (8e).



Horizontal milling machine with provision for alternative work heads

The American Scene

BY OUR AMERICAN EDITOR

Another Wonder Metal

Following closely in the footsteps of the development of titanium, the "wonder metal" of a few years ago, zirconium and its alloys are currently the most discussed materials on the American industrial scene. While titanium received its greatest impetus from applications in the aircraft and chemical industries, atomic energy is the field of use which is to-day primarily responsible for the greatly accelerated production of zirconium. After many years as a laboratory curiosity, zirconium is moving into the volume production stage. Although the output of the metal still is measured in pounds rather than in tons, volume will jump sharply under a programme of the U.S. Atomic Energy Commission to obtain 1000 tons annually over the next five years. Moreover, the metal's exceptional ability to resist corrosion and its ease of fabrication promise to open up substantial commercial markets for it in the future. Three companies, Carborundum, National Distillers and Chemical, and National Research, are at present completing or enlarging their zirconium facilities to fulfil the A.E.C. contracts. Several other chemical and metal producers either are already in the field in a limited way, or are contemplating entering it. Included in this list are Kawecki Chemical, Union Carbide, and the Titanium Metals Corporation of America, the last-named being owned jointly by the Allegheny Ludlum Steel Corporation and the National Lead Company. Still another joint venture is that of Reactive Metals, Incorporated, owned by National Distillers and the Mallory-Sharon Titanium Corporation. Reactive Metals was organised to build a works for melting zirconium and its alloys, and to manufacture certain zirconium mill products. First isolated as a metallic element in 1824, zirconium found little use until the development of atomic power. The principal difficulty has been that of isolating the pure metal, since it combines readily with oxygen, hydrogen, nitrogen, silica and carbon, and into alloys with aluminium and magnesium. Most of the small American output to date has been produced by the U.S. Bureau of Mines, but the soaring demand from the A.E.C. for zirconium for use in thermal reactors has necessitated the building of substantially larger facilities. As zirconium became the preferred construction material for the core and fuel element cladding of pressurised water reactors, including those of the highly successful American nuclear-powered submarines, the A.E.C. turned to larger-scale commercial sources of production. A year ago the Commission awarded contracts to three companies as part of a five-year programme to obtain a total of 5000 tons of the metal.

Although virtually all American output currently is for the A.E.C., the zirconium producers have high hopes of developing large civilian markets. In addition to its excellent anti-corrosive properties—superior even to stainless steel—zirconium is extremely resistant to most acids and alkalis, has a very high melting point and is resistant to the caustic effect of fused metals. It is as strong as steel, but somewhat lighter, and can be fabricated into any shape. All these qualities combined in one metal make zirconium particularly promising for chemical processing equipment, despite its current high price. Zirconium alloys or compounds already are being employed on a growing scale in steel casting, armour plating, as a cleansing agent for oxides, as furnace linings and in crucibles, enamels and porcelain. The largest of the A.E.C. contracts went to the National Distillers and Chemical Corporation, which has been expanding its chemical division rapidly in recent years. National Distillers will supply the Commission with 1,000,000 lb of zirconium metal annually over the next five years. The firm's original plans called for a plant with production capacity sufficient to satisfy the Government demands, as well as estimated initial commercial needs. Construction is under way at Ashtabula, Ohio, and the facilities are scheduled to come on stream by this summer. Earlier this year, however, National Distillers raised its sights on zirconium and decided to boost the works capacity from 1,500,000 lb to 2,000,000 lb annually. Half of this enlarged capacity will be available for commercial users. The company plans to sell hafnium-free zirconium sponge or pellets on the open market at prices ranging from 4·75 dollars to 6·50 dollars per pound, depending on quantity, compared with the present 12 dollars per pound price for sponge. Hafnium is a closely related metal, which must be removed from zirconium for use in reactor construction, since it absorbs neutrons at a high rate. Commercial grade zirconium, not hafnium-free, will sell for about 1·50 dollars less than the pure material. The N.R.C. Metals Corporation was formed by the National Research Corporation in May, 1956, and has the second largest A.E.C. zirconium contract. It will deliver a total of 3,500,000 lb of reactor-grade zirconium and hafnium to the A.E.C. over the five-year period, at a price of approximately 23,000,000 dollars. Construction of a plant is well under way near Pensacola, Florida, and initial production is due late this summer. The third A.E.C. supplier, the Carborundum Company, is an established producer of abrasives, which in recent years has emphasised the development of new electro-metallurgical minerals. Carborundum completed an expansion of its existing zirconium sponge facilities in Akron, New York, last year and received a contract to supply the Commission with an additional 2,500,000 lb of zirconium over the next five years. A new works at Parkersburg, West Virginia, to provide capacity for the new A.E.C. contract, is expected to be in operation shortly.

Produced commercially for less than five years, the history, technology and development pattern of zirconium is almost a carbon copy of its better-known sister metal, titanium. The latter was discovered in 1789, but, like zirconium, had virtually no market until the post-war development of jet aircraft. Limited commercial American production of titanium got under way in 1948 and output totalled only 25 tons in the following year. However, output soared to 14,500 tons last year, and the rapid plant expansions should increase volume substantially by 1960. The output of zirconium by the three commercial producers will total 1000 tons annually under the A.E.C. contract, which is somewhat ahead of where titanium stood in the United States in 1952. The zirconium producers, like the titanium makers, are involved in an intense technological race. The Bureau of Mines process, which has been in use in the carborundum plant since 1953, is the Kroll batch reduction method used for titanium. However, the search is on for a continuous, rather than a batch, process, just as it is in titanium. National Distillers reportedly is ready to try out an Australian hafnium separation process; the company already claims that its sodium reduction process will produce both zirconium and titanium at lower costs than any other method now in commercial use. National Research will use still a third zirconium process; its details have not been revealed, except that it is continuous. The large Union Carbide organisation is exploring the feasibility of using thermal diffusion to produce zirconium. Its nuclear division has awarded a research contract to the University of Tennessee for the study of such a process. Kawecki Chemical, a small producer of chemicals, and the less familiar metals and alloys, is stressing the production of double fluoride salts of zirconium, titanium and boron. Its line of master alloys, which was introduced late in 1955, has been well received by the aluminium and other metallurgical industries. To date, however, Kawecki has placed even more emphasis on tantalum, another "new" metal that is more costly and not as far along in its development as zirconium. It has worked out a new process for tantalum production, and is offering it in a wide variety of forms, including chemical compounds, metal bar and ingot, and such fabricated mill products as strip, foil and wire. The best source of zirconium is considered to be zircon sand. This is a hard, abrasive, crystal-like substance found in sand in many parts of of the United States, but particularly in Florida, North Carolina and California. It also is plentiful in Australia. A second—and probably the largest—source of zirconium is Brazilite, a black oxide ore available in large quantities in Brazil. Still other zirconium-bearing ores are found in Colorado. Florida, which is rich in the titanium ores rutile and ilmenite, also has attracted much attention for its zircon sands. National Research chose Pensacola as the site for the big zirconium works of its N.R.C. Metals affiliate, largely because of its proximity to the Florida zircon sands. It claims that these represent America's largest and most accessible deposits of zirconium ore. If the present rate of progress in plant construction can be maintained, the company claims that it will have the world's largest completely integrated zirconium works in full production in 1958. All this activity in zirconium not only should increase the supply of the metal and its alloys, but also bring prices down. This in turn should open important commercial markets—just as it has done in titanium. Only in this manner can a widespread engineering application of the metal be brought about, based on its general physical and chemical properties and not merely on its ability to pass slow neutrons and sustain chain reactions.

Fast Telephone Transmission of Data

THE Bell Telephone Laboratories, of New York, have announced a new experimental device which will enable business machines to "talk" directly with one another at a speed of about 1000 words a minute. Printed material could thus be sent over lines like those used for telephone purposes, but at a speed sixteen times that of conventional teletypewriter systems. The new device has tentatively been called a data subset and is designed to give accurate transmission among wide varieties of information processing machines, such as electronic computers, electric typewriters or adding machines. The transmission of the data is automatic, and voice communication can precede or follow the operation.

Information is placed on magnetic tape by an electronic computer, electric typewriter or other machine. In contrast to holes punched in paper tape used in many other automatic machines, letters, numbers or symbols are placed on the magnetic tape in the form of magnetised spots. A group of seven such spots identifies the particular character. Some spots are magnetised in such a way that they represent "zero" and others in a way that represents "one." All information put on the tape is translated into a code using combinations of these two numbers. The chief advantage of magnetic tape is that its speed is easily adapted to match the speed with which the signals can be sent over telephone wires. It also has the advantage of quiet operation. After its preparation, the tape is inserted into the data subset machine. The person on the "sending" end talks by telephone with the person on the "receiving" end to notify him that the message is to be transmitted. The recipient turns on a receiver mechanism and the sender then starts transmission. An automatic signal indicates when the taped message is completed. The person on the receiving end removes the tape from the machine and inserts it in the office machine for decoding. On an electric typewriter, for example, the mechanism could be arranged to type out the message automatically from the magnetic tape. This would be set for the speed of the typewriter and could be at a faster speed than a typist could attain. To provide essentially error-free transmission, extra error-checking equipment can be added. In the event of a disturbance in transmission, the receiving equipment will then reject the portion of the transmission affected and automatically cause it to be retransmitted.

The present laboratory models are about the size of office typewriters. If they were designed for maximum compactness, they could be made considerably smaller. The small and convenient size is made possible by the use of transistors, semi-conductor diodes and ferro-electric crystals. No vacuum valves are used. The functions of memory, logic, oscillation, modulation and amplification, which would ordinarily be performed by vacuum valves and their associated components, are here performed by the products of solid-state electronics. By the use of transistors, the machine can be one-twentieth the size required if vacuum valves are used. The use of transistors reduces the power requirements to about 5 per cent of that necessary to operate a like machine built with vacuum valves. Because of its great speed, the equipment uses the information-handling capacity of telephone circuits with high efficiency. In many instances there is no urgency requiring that a message be sent at 1000 instead of 100 words per minute. But, for a given amount of information, the machine reduces drastically the amount of time the telephone line would need to be used. The equipment could be set up to function in off-peak telephone traffic hours. For example, the subset could transmit over one line from 5 p.m. until 9 a.m. the following day the equivalent output of some thirty expert typists typing at full speed for eight hours.

Typewriter preparation of the magnetic tape is only one of many methods which could be employed. More complex business machines would perhaps find even greater use for this type of transmission system. For instance, a bank might employ an electronic computer to compile account numbers, deposits, withdrawals and balances. By placing the data on magnetic tape, the bank could quickly send the information to one or several branch locations simultaneously.

World Warning Agency for the International Geophysical Year

As from July 1, the National Bureau of Standards radio forecasting centre at Fort Belvoir, Virginia, is serving as the focal point of a world-wide communications network for the International Geophysical Year. From this point, warnings will be transmitted to scientists throughout the world to help in their observational efforts in anticipation of unusual activity in cosmic rays, aurora, earth magnetism, and wireless propagation disturbances. The warnings will be based mainly on world-wide observations of the surface of the sun and on soundings of the ionosphere. The N.B.S. field station has been selected as the I.G.Y. World Warning Agency by the U.S. National Committee for the I.G.Y.

In addition to the N.B.S. station at Fort Belvoir, the international network includes the radio teletype network of the World Meteorological Organisation, virtually all of the commercial communications facilities throughout the world, government facilities and special messages broadcast by stations WWV and WWVH on the N.B.S. radio propagation forecast channels and their counterparts in other countries. This elaborate and far-reaching network has been set up so that the scientists participating in the I.G.Y., no matter how remote the site of their work, can conduct their experiments simultaneously. Since January, 1957, the warning system has been undergoing a week of advance trials each month. Because it is not economically feasible for scientists to make intensive world-wide observations every day during the I.G.Y., a series of "Regular World Days" has been selected in advance for more detailed simultaneous observations. These regular world days will be supplemented from time to time by two types of warnings—Alerts and Special World Intervals—which the I.G.Y. World Warning Agency will issue when major solar-terrestrial disturbances are expected. The alerts will be used to notify scientists that a Special World Interval may be called in a few days. The Special World Interval will be called on about eight hours' notice when there is a strong possibility that a major solar-terrestrial disturbance will begin within twenty-four hours after the start of the interval. The interval will end when the disturbance subsides, or in about twenty-four hours, should the predicted disturbance not materialise.

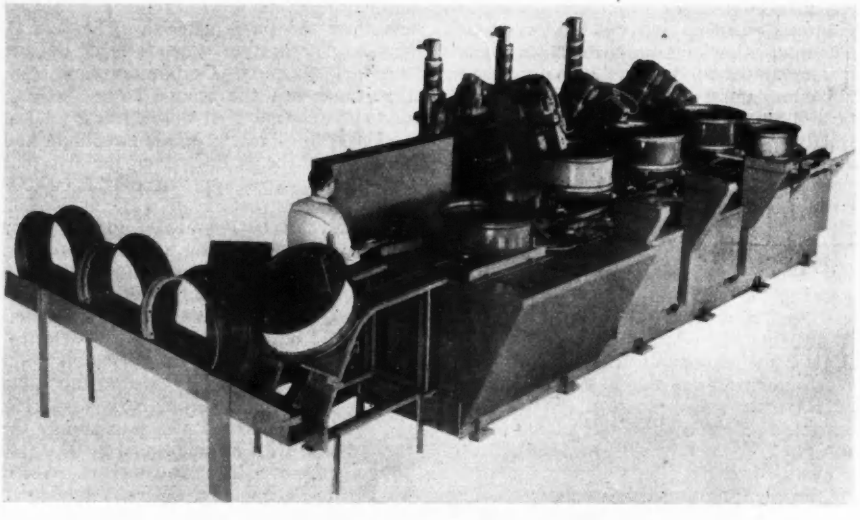
Studies in ionospheric physics, geomagnetism, solar activity, cosmic rays and aurora will be intensified during Special World Intervals. Some special cosmic ray balloon flights and rocket launchings may be made during these periods, with experiments on a stand-by basis, awaiting notification of special conditions from the world warning centre. By 1600 hours G.M.T. each day, the World Warning Agency will decide whether to call an Alert or Special World Interval for 0001 hours G.M.T. the following day or not. This decision will be made with the advice of ionospheric and solar observatories and communications forecasting centres both in the United States and abroad. If the solar conditions justify calling an Alert or Special World Interval, the World Warning Agency will issue messages to Regional Warning Centres in the Netherlands, France, Germany, Japan, and the U.S.S.R., and then to Associate Warning Centres in Australia, Antarctica and Alaska. From these centres, the warnings will be transmitted to every I.G.Y. field station throughout the world. The forecasting centre in Virginia will also serve as the Western Hemisphere Regional Warning Centre. In the United States itself, the messages will be put on the U.S. Weather Bureau communications system, so that all U.S. Weather Bureau stations will be alerted. It is then the task of each Weather Bureau station to inform all the other I.G.Y. field stations in its locality.

Automatic Transfer Machine for Processing Large Wheel Rims

A FIVE-STATION machine that automatically performs the operations of embossing, piercing and chamfering on large wheel rims has been developed by the Hautau Engineering Company, of Ferndale, Michigan. Three 50-ton hydraulic "C" frame presses are integrated with a high-speed in-line transfer mechanism in the machine, which is shown in the accompanying illustration. The presses are flexible in operation, being capable of rapid adjustment in three planes as well as a rotary adjustment. This flexibility greatly simplifies the dies required for the production of different rims.

The heavy "C" frame units are rapidly advanced on ballways to the pressing position by an air cylinder. The press ram, in turn, is powered by a hydraulic booster cylinder and has a pressing stroke of 2in. The transfer mechanism is hydraulically powered by a parallel rack arrangement to effect up and down movements on ballways through a distance of 10in. A three-station travelling carriage transfers the rims when the lift mechanism is in the down position. Mounted to the lift mechanism at each station are adjustable clamps for clamping the various diameter rims. The travelling carriage reciprocates on large V-rollers, progressively transferring the rims from one station to the next.

The wheel rims roll down an incline to the loading station, where a mechanical loader elevates the rim to the loading station. The travelling carriage shuttles the rims in process to their next stations. The power clamps are actuated, clamping the wheel rims in all stations. The rims are then elevated to the pressing



Five-station transfer machine for processing large wheel rims

position. The presses are powered to perform the embossing operation at station 2, piercing the valve stem hole at station 3 and chamfering at station 4, stations 1 and 5 being the load and unload stations. After the pressing operation is complete the elevating mechanism is lowered and the rims unclamped. The rims are then transferred to the next stations. Each pressing station is powered by a 6in hydraulic booster cylinder, which in turn is operated by a separate pump unit. Each pump is powered by a 20 h.p. electric motor. All three motor pump units are mounted on a 200-gallon reservoir. The machine is approximately 15ft by 35ft by 7ft high, and it produces approximately 400 rims per hour.

Linear Accelerator at the University of California

A NEW linear accelerator designed for the study of the elements and isotopes in the transuranic region, including an attempt to synthesise atoms heavier than element 101, has gone into operation in the University of California Radiation Laboratory. The machine, which is called "Hilac," is now accelerating nuclei of nitrogen atoms to energies of 140MeV. The new instrument does not compete in energy with such ultra-powerful machines as the Bevatron, which accelerates protons to 6200MeV. In contrast, the new machine is designed especially to accelerate the nuclei, or ions, of very heavy atoms. It is therefore called a heavy ion linear accelerator, or "Hilac." It may permit the synthesis of elements heavier than Mendelevium, the heaviest now known. The elements heavier than uranium are all synthetic and are obtained by transmuting uranium nuclei, step by step, into successively heavier atoms.

The machine represents, in part, a joint project between the University of California and Yale University. Yale and Berkeley scientists jointly developed the design of the machine, a duplicate of which is nearing completion now at New Haven, Connecticut. The research emphasis at the two institutions will be different—Yale being chiefly interested in problems in physics and Berkeley giving priority to chemical transmutation experiments.

There are a number of difficult problems about synthesising elements heavier than 101. As nuclei become heavier they become less stable, their half-lives become shorter, the number of atoms that can be synthesised becomes smaller and their detection becomes more difficult. In the case of element 102, the scientists would expect even fewer atoms from alpha particle bombardment than in the case of element 101, and their half-lives would be measured in seconds and fractions of seconds. To add to the problem, fission is the most common reaction that takes place in any bombardment that might produce element 102. "Hilac" is designed to accelerate the nuclei of atoms ranging up to argon. Therefore, it may be possible to add very large fragments of matter to target nuclei, bringing about big jumps up the periodic table in single transactions.

Tumbling Machine for Jet Engine Components

To accelerate the production of complex stainless steel jet engine components, the Des Moines works of the Solar Aircraft Company in Iowa are now using specially designed and built tumbling machines. One of the new tumbling machines, shown in the accompanying illustration, has a drum about 6ft long and 4ft in diameter. A central shaft in the machine holds up to fourteen of the Solar vane and shroud assemblies which are major components of the "J.57" turbo-jet engine. In use, the jet components are held rigidly on the central shaft, while the large tumbling barrel slowly rotates. The barrel contains an abrasive charge—a mixture of aluminium oxide chips, pieces of mild steel wire and water. As the barrel revolves, the abrasive mixture hones and polishes the sharp edges and nicks, wearing them smooth and clean. The vane and shroud units that are finished in the tumbling machines are intricate assemblies, consisting of inner and outer shroud rings connected by as many as 160 air foil vanes.

The installation includes a special conveyor system which hauls the abrasive charge to an overhead hopper, from which it is gravity-fed back into the tumbling barrel each time a new load of parts has been fixtured. The abrasive charge for each barrel weighs 2 tons. Before the firm obtained the tumbling units, the vane and shroud assemblies were deburred by using hand air grinders, automatic vapour blast units and automatic wash cabinets. Often inspection after these operations would reveal remaining nicks or sharp edges; one hour or more was required for the finishing cycle. The new tumblers completely eliminate hand deburring, vapour blast and wash operations, and are 75 per cent faster. Other advantages obtained are a smaller possibility of damage to the precise jet components; a better mating of parts in the completed engines; a better balance, and an increased life of the components.

Machine for tumbling jet engine components with abrasive conveyor system

Smallest Aircraft Turbine

SOLAR AIRCRAFT COMPANY, of San Diego, is designing and preparing to produce the smallest gas turbine aircraft engine ever built. Only 20in high, with maximum diameter of 15½in and weighing only 50 lb, the tiny engine will produce 55 s.h.p. plus 12 lb of jet thrust, and it will be used to power a one-man helicopter. The turbine speed will be 57,600 r.p.m., and standard military fuels will be used.

The company is to produce the new engine under a joint contract from the Navy Bureau of Aeronautics and the U.S. Army. Known as the Solar "Mercury," the engine's military designation is the "YT-62."

The new engine is the first to be designed and built by Solar specifically for aircraft propulsion. Other Solar gas turbines are the 50 h.p. "Mars," the use of which as an aircraft auxiliary power unit was described on page 66, July 13 last, the 500 h.p. "Jupiter," and the 1000 h.p. "Saturn."

Liquid-Sodium-Cooled Heavy-Water-Moderated Reactor

THE U.S. Atomic Energy Commission has contracted with the Nuclear Development Corporation of America, White Plains, New York, for research, development and preliminary design work necessary to demonstrate the feasibility of a liquid sodium-cooled, heavy-water-moderated reactor system. The estimated cost of the work under this contract is 1,725,000 dollars. The work under this contract looks toward the construction and operation of a nuclear electric power station in Anchorage, Alaska, under a three-party agreement now being negotiated among the Nuclear Development Corporation, the Chugach Electric Association of Anchorage, Alaska, and the Commission. The project has been divided into three phases: first, initial design and development; second, final development and engineering design; third, construction, start-up and operation. The contract with the Nuclear Development Corporation covers work under the first phase. Negotiation is under way on a contract which would cover the remaining phases of the project. These remaining phases would be undertaken only if the preliminary work to be done under the present contract demonstrates that the reactor concept is feasible. The Commission has determined that the successful combining of heavy water as moderator and liquid sodium as coolant would constitute an important technical advance in power reactor technology. A significant amount of research and development is considered necessary to develop technology combining the two in a single reactor system.

Experimental Nuclear Facility

THE Atomic Energy Commission has granted permission to the Glenn L. Martin Company of Baltimore, Maryland, for the construction of a nuclear experiment facility at Middle River, Maryland. The proposed facility is to be housed in a building situated within the boundaries of the Martin Airport and will have two critical experiment cells operating independently of each other. The initial experiments will relate to the Martin Power Reactor (MPR) and to systems similar to the U.S. Army Package Power Reactor (APPR). In the MPR experiment the reactor design to be investigated is a heterogeneous, water-moderated, pressurised system, using stainless steel clad enriched tubular fuel elements. The assembly will be a prototype of the core of the Martin Power Reactor and will be used to check theoretical calculations and predict the nuclear characteristics of the reactor.

Flat plate fuel elements will be used in the APPR critical facility. The uranium fuel will be in the form of foils with stainless steel plates on both sides of the foils. For each assembly the core will be supported in an aluminium tank in a concrete pit. The test cell walls and roof will be of monolithic reinforced concrete. The experiments will be conducted at or near zero power, and the maximum power will not exceed 10W.

Personal and Business

Appointments

MR. J. B. STRIBLING has been appointed a director of Acme Ventilating, Ltd.

MR. H. E. STEEL has been appointed a director of Burness, Corlett and Partners, Ltd.

MR. R. J. DIXON and Mr. S. W. Perkins have been appointed directors of Arthur Scrivener, Ltd.

SIR ALEXANDER SIM has been appointed a director of W. T. Henley's Telegraph Works Company, Ltd.

THE HONORABLE ALEXANDER L. HOOD has been appointed a director of George Wimpey and Co., Ltd.

MR. ROBERT ATKINSON, M.I.Mar.E., A.M.I. Mech.E., has been appointed managing director of Hamworthy Engineering, Ltd.

TECALEMIT, Ltd., has announced that Mr. A. Muir, M.I.Mech.E., has been appointed manager for the Scottish and Northern Ireland region.

THE BRITISH CAST IRON RESEARCH ASSOCIATION has announced the appointments of Mr. H. Morrogh as deputy director, and Dr. H. T. Angus as assistant director to Dr. J. G. Pearce.

THE SPERRY GYROSCOPE COMPANY, Ltd., has announced that Lt./Cdr. Peter W. Armitage, A.R.Ae.S., has been appointed service manager in succession to Mr. H. O. Essex.

MR. W. GEORGE PINDER has been appointed managing director of Crossley-Premier Engines, Ltd., in succession to Mr. A. Cyril Yeates who retired on April 30. Mr. Yeates remains a director.

MR. F. E. BEAKE has been appointed manager of the Plymouth sales office of Brook Motors, Ltd. Mr. J. B. Abbott has been appointed to succeed Mr. Beake as sales engineer at the Manchester office.

THE WESTINGHOUSE BRAKE AND SIGNAL COMPANY, Ltd., has announced that Mr. G. W. H. Richardson, Mr. T. J. Aldridge, Mr. N. G. Gadman, Mr. J. W. G. Kershaw and Mr. L. E. Thompson have been appointed directors.

THE NORTH WESTERN ELECTRICITY BOARD has announced that Mr. Harold Lees Partington has been appointed to succeed Mr. Percy Clegg as sub-area engineer of the Board's No. 7 sub-area. Mr. Clegg has retired.

THE MINISTRY OF LABOUR AND NATIONAL SERVICE has announced that Mr. Alfred Richardson, deputy public relations adviser to the Prime Minister, has been appointed chief information officer, Ministry of Labour and National Service, in succession to Mr. Lex Hornsby.

LONDON TRANSPORT states that Mr. E. Webster, A.M.I.E.E., has been promoted to principal development assistant and will report to the assistant mechanical engineer (development) railways. Mr. G. F. Noakes has been appointed principal stores assistant and will be responsible to the supplies officer for the control of the stores organisation.

Business Announcements

MR. J. W. MILLS, M.I.Mech.E., a director of Armstrong Whitworth (Metal Industries), Ltd., and Yarrow Metal Industries, Ltd., has retired.

THE STANDARD PRESSED STEEL COMPANY states that it is planning to acquire Columbia Steel Equipment Company, Inc., through an exchange of stock.

HENRY HARGREAVES AND SONS, Ltd., Cook Street, Bury, Lancs, has announced the opening of a London office at 603, Grand Buildings, Trafalgar Square, W.C.2 (telephone, Whitehall 4805).

GEORGE H. ALEXANDER MACHINERY, Ltd., states that it has been appointed sole midland agent stockist for the "Jessop-Saville" range of carbon and alloy tool steels manufactured by William Jessop and Sons, Ltd., and J. J. Saville and Co., Ltd.

THE EDISON SWAN ELECTRIC COMPANY, Ltd., and Siemens Brothers and Co., Ltd., state that subject to Board of Trade formal consent to the change of name, the business at present carried on by the companies separately will be merged and carried on, as from July 1, by Siemens Brothers and Co., Ltd., under the new name of Siemens Edison Swan, Ltd.

THE VILLIERS ENGINEERING COMPANY, Ltd., Marston Road, Wolverhampton, has announced that Mr. Frank H. Farrer, chairman, has resigned from active participation in the affairs of the company. He has been appointed the company's first president, an honorary position.

JET-LUBE, Ltd., 26/32, Caxton Street, Westminster, London, S.W.1, states that it has been formed to manufacture and market in Europe, the Middle East, and the Far East, its lubricants, greases and grease compounds, formerly only obtainable from the United States.

JOHN LAING AND SON, Ltd., and the H. K. Ferguson Company of Great Britain, Ltd., jointly state that the two companies have formed a separate association in the name of "Laing-Ferguson," to provide a construction service to the chemical, processing and manufacturing industries.

CHAMBERLAIN INDUSTRIES, Ltd., states that it has appointed Hailes Plant Sales and Hire, Ltd., 81, Great King Street, Edinburgh, 3, and Royal Exchange Buildings, Glasgow, C.2, as its Scottish distributor, to handle sales of "Jenbach" air compressors and the "Staffa" mobile and shop cranes.

LONDON TRANSPORT states that the separate North and South divisional organisations (country buses and coaches) have been abolished and replaced by a single divisional organisation under the control of a divisional engineer (country buses and coaches) who is an officer of the executive. Mr. W. I. Kirshner has been appointed to this post. Mr. H. F. C. Adcock, divisional superintendent (south) country buses and coaches, has been appointed an officer of the executive, and Mr. D. H. Mills, principal executive assistant, has been promoted an officer of the executive with the title of establishment officer.

Contracts

BRISTOL AIRCRAFT, Ltd., announces that two "Britannia" 300 airliners have been ordered for delivery to Aeronaves de Mexico within the next few months. The machines are intended to enable the airline to meet intense competition on the New York-Mexico City route.

Miscellanea

BIRTHDAY HONOURS.—Our apologies are due to Mr. Wilkin Scott, Managing Director of Armstrong Whitworth and Co., Ltd., whose name was omitted from the list of Birthday Honours published in our issue of June 21. We congratulate Mr. Scott on being made a Knight Batchelor.

AIRCRAFT BONDING.—A film describing the purpose and methods of applying "Redux" bonding to aircraft structures has been produced by Aero Research, Ltd., Duxford, Cambs. It is in colour and 16mm size; sound tracks have been made in English (optical), French, German, Italian and Japanese (magnetic).

REFRIGERATOR CONTROL EQUIPMENT FACTORY.—A new factory has been opened at Uddington, Glasgow, by Ranco, Ltd., for the manufacture of domestic and commercial refrigerator control equipment, rotors and stators for refrigerators, and thermostatic controllers for motor cars. This factory has a productive floor area of some 160,000 square feet and employs about 1300 hands.

MULTI-UNIT TALLY COUNTERS.—A simple multi-unit tally counter adaptable for use in a variety of industrial departments such as stores, production control offices or warehouses, has been introduced by County Instruments, Ltd., 5, Elstree Way, Boreham Wood, Herts. Each counter assembly consists essentially of tally units arranged in tiers of five, and, as a standard, an assembly can be supplied up to five tiers high. Each counter is provided with a recess into which an identification slip can be inserted, and is operated by a light push button. The counters tabulate in single units up to 9999 and a zero reset is provided.

HIGH-SPEED RESONANCE SCREENS.—A licence has been acquired by W. J. Jenkins and Co., Ltd., of Retford, from Schuchtermann and Kremer-Baum of Dortmund, for the manufacture in the United Kingdom of the complete range of the German firm's high-speed resonance screens. The screens are to be manufactured in six different widths, from 4ft to 7ft 4in, and in units of length to suit the material being handled. The upper limit for the length of one unit is generally in the region of 22ft and where longer screens are required two units may be arranged in tandem. Inputs of up to 400 tons per hour can be handled, depending on the density and size of the material, and the vibration characteristics can be modified to suit the material and screening application.

LITHIUM BASE GREASES.—The range of "Alvania" lithium base greases made by Shell-Mex and B.P., Ltd., now contains a water-soluble corrosion inhibitor which gives a high degree of resistance to corrosion when the greases are used in bearings to which water has access in service. These greases, based on lithium 12 hydroxy stearite, have a high degree of mechanical stability over a wide temperature range, whilst they resist drying-out and hardening in service. Under certain limited conditions tests have shown that the maker's "Alvania" grease 3 can be used effectively in rolling bearings at temperatures up to 135 deg. Cent.

METALLIC MOULDABLE PASTE.—A metallic paste compound, known as "Metolux," developed by M.G. Plastics, Ltd., 19, Mincing Lane, Blackburn, Lancs, can be used as a cold setting filler or for building up defects in metallic parts such as castings, jigs, tools, &c. It is applied in the form of an easily spread paste which comprises a liquid constituent of thermosetting plastics and a powder containing finely divided metals, and it sets in about thirty minutes after application. Once it has set, the filler can be machined as a normal composite metallic part of the article to which it has been applied. "Metolux" is now being distributed by Stedall and Co., Ltd., 164, High Holborn, London, W.C.1.

TITANIUM ALLOY.—A new titanium bar and forging alloy containing 6½ per cent aluminium and 3¾ per cent molybdenum is now available in experimental quantities from Rem-CRV Titanium, Inc., whose agents in this country are Henry Gardner and Co., Ltd., 2, Metal Exchange Buildings, Leadenhall Avenue, London, E.C.3. Compared with existing alloys, the new material shows improved strength at high temperatures; at 1000 deg. Fah. yield being 40 tons and ultimate 47 tons and excellent time-temperature-stress stability, samples exposed to high stresses between 600 deg. and 1000 deg. Fah. showing undiminished strength and excellent ductility at room temperature. Laboratory results show deep hardenability, strengths over 70 tons with good ductility having been secured in sections over 2in thick.

CONTINUOUS WEIGHING.—A continuous supply of material at a preset weight per unit of time can, it is claimed, be sustained with great accuracy by the feeder units evolved by Sinex Engineering Company, Ltd. The constant weight feeder consists essentially of a short constant-speed belt conveyor carried by a centre-zero weighing machine. Material is fed on to the belt by a vibratory hopper, and the input to the vibrator is varied by a thyratron circuit in proportion to the error indicated by the weighing machine. The response of the control equipment and feeder is so precise that the delivery in thirty-second periods has been known to vary less than 0·15 per cent over twenty-four hours. The principle has been applied to machines varying between 250 lb and 6 tons per hour.

DOPPLER NAVIGATION.—Doppler navigation has for some time been favoured for military purposes, largely because of its independence from ground installations, but its ability to provide the aircraft with knowledge of its ground speed, and hence of prevailing wind velocity, justifies its use on civil aircraft. Marconi's Wireless Telegraph Company, Ltd., Chelmsford, Essex, have now introduced a Doppler navigator, type A.D. 2300, for commercial use. Beams are projected in sequence forward and backward, slightly to port and slightly to starboard. The ground speed is derived from the difference in frequency between reflections from in front and behind the track by finding an aerial angle at which displacement to either side has the same effect. The resulting information is fed by synchros to the computer. Compass heading and air speed are similarly supplied, and, by electrical and mechanical analogues, such information as present position, distance to destination or change of course, and deviation from desired shunt line or great circle. The calculation is accurate up to ±80 deg. latitude, variation being stored on a cam if a magnetic compass is used. A smaller indicator can displace the computer if ground speed, drift angle and distance flown only are required. The equipment will operate between 150ft and 50,000ft and at speeds between 80 and 900 knots. It weighs 130 lb complete.

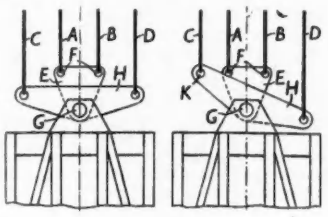
British Patent Specifications

When an invention is communicated from abroad the name and address of the communicator are printed in italics. When an abridgment is not illustrated the specification is without drawings. The date first given is the date of application; the second date, at the end of the abridgment, is the date of publication of the complete specification. Copies of specifications may be obtained at the Patent Office Sales Branch, 15, Southampton Buildings, Chancery Lane, W.C.2. Price 3s. 6d. each.

MINING MACHINERY

777,297. June 10, 1955.—Equalising Device for Distributing a Load Between Two Pairs of Ropes, Gutehoffnungshutte Sterkrade Aktiengesellschaft, Lipperfeld 1, Oberhausen Rhineland, Germany.

This invention relates to an equalising device for distributing a load between at least two pairs of ropes, particularly for hoists in mine shafts, where the desire to lift increasing loads from increasing depths has induced the use of a number of cables for suspending the cage or skip. The example illustrated in the drawing is a four-cable suspension. The two inner cables *A* and *B* form an inner pair of cables, the two outer cables *C* and *D* form an outer pair. The inner cables are connected to a triangular equalising lever *E*, whose connecting bolts *F* are disposed above the pivot pin *G* carried by the cage or skip. The two outer cables are associated with a second equalising lever *H*, which has about twice the length of the inner equalising lever *E* and is carried by the same pivot pin *G*. The points *K* where the cables *C* and *D* are connected are also disposed above the pivot pin *G*. The two equalising levers *G* and *H* can swing from



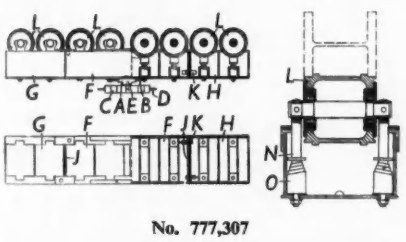
No. 777,297

their illustrated horizontal intermediate position independently of each other towards both directions to equalise the load between the two individual cables. This free swing of the two levers may be limited, e.g. by forming the connecting bolts *F* of the inner lever *E* as stops extending in the swing path of the lever *J*. When both levers swing in the same direction, towards the right, the inner lever will reach its end position when the left-hand connecting bolt of the cable is vertically over the fulcrum axis. The head of the cage may serve as a stop for limiting the swing of the lever *H*. The invention is not restricted to application to the illustrated example of a four-cable suspension but may be used also, e.g. for a six-cable suspension with a third equalising lever for the outer pair of cables, which may be carried on the common pivot pin or may have a separate fulcrum axis disposed on the vertical axis of the cage which extends through the centre of gravity of the cage.—*June* 19, 1957.

STRUCTURAL ENGINEERING

777,307. September 5, 1955.—Roller Box for Advancing Bridge Components, Aktiengesellschaft Fur Unternehmungen Der Eisenund Stahlindustrie, Altendorferstrasse 103, Essen, Germany.

The invention relates to a roller box for advancing bridge components during bridge building. The



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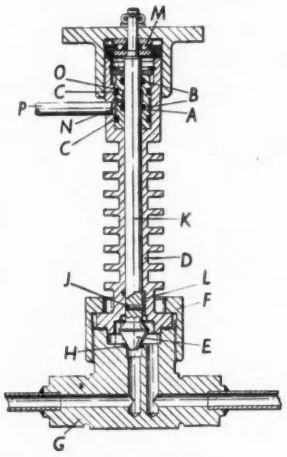
rollers are normally mounted on superposed balance beams in order to obtain uniform loading. In the drawing, a tilting support *A* having handles *B*, rests upon a base member *C* having handles *D*. The tilting support *A* carries holding pins *E* which engage with play in the base member in order to allow a tilting movement. Mounted upon the tilting support is a frame *F* which, in conjunction with end frames *G* and *H*, forms the roller box. The facing end faces *J* of the frames are secured against lateral displacement by bolts *K*. Rollers *L* are arranged in the roller box in series on axles. The ends of the axles rest on supports *N* supported by springs *O*. In order to allow the rollers *L* to tilt when necessary the ends of the axles are connected by ball joints to the supports *N*, as shown in the right-hand view. The load exerted upon the rollers by a bridge component placed upon the roller box is uniformly distributed over all the supporting springs so that over-stressing of individual supporting springs does not have to be feared. The lower ends of the flanges of the bridge component are supported on the rollers *L*, as shown. Sometimes these lower edges assume a curvature due to bending of the component. The load due to the weight of the component is, nevertheless, shared by the rollers on which it is supported, but in this case some of the rollers will be depressed against their supporting springs more than others. In order to ensure the maximum uniformity of loading of the supporting springs, the roller box is preferably capable of bending under vertical loads so that, in the event of bending of the supported bridge member, the roller box may assume a corresponding curvature.—*June* 19, 1957.

VALVES

777,039. July 25, 1953.—Valves for Controlling High Temperature Fluids, The United Kingdom Atomic Energy Authority, of London. (*Inventor: Frank Leslie Speed.*)

It is an object of the invention to provide a valve which makes use of a self-sealing resilient gland when controlling the flow of a high temperature fluid, the fluid being at temperatures above the maximum operating temperature of the resilient gland. The valve shown in the drawing has a ¾in bore and is designed to operate at a body temperature of 500 deg. Cent., at which temperature the insert *A*, carrying the O-seals *B* and *C*, is at 80–90 deg. Cent. This is achieved with fewer fins than usual, it having been discovered that the temperature at the insert is mostly dependent on the length of the sleeve *D*, which is 4in, and the number of fins is not critical. The closure number *E* is made integral with the spindle and is made of 18/8 austenitic stainless steel and the clamping ring *F* in this embodiment is screwed instead



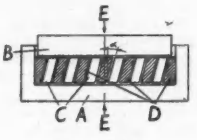
No. 777,039

of being bolted to the body *G*. The closure number *E* is arranged to seat against a "Stellite" grade 1 seal *H*. It will be understood that the body, spindle and sleeve may be made of any other suitable low conductivity material compatible with the working fluid and that similarly any other suitable seal may be provided. A pin *J* in the spindle *K* is arranged to engage a keyway *L* in the sleeve *D*, to prevent rotation of the spindle and a ball thrust race *M* is substituted for the thrust washer. A clearance of about $^{1}/_{64}$in is provided between the spindle and the sleeve *D* and the working fluid therefore reaches the gland but only at the temperature of the sleeve. The insert *A* is made of nylon and is provided with two synthetic rubber O-ring seals *C* between it and the sleeve *D* as well as two similar O-ring seals *B* between it and the spindle *K*. The two seals *C* enable annular cavity *N* to be provided on the outside of the insert in communication with the annular cavity *O* so that by means of a duct *P* a sample can be taken of any fluid which might pass the inner O-rings of the seals.—*June* 19, 1957.

POWER TRANSMISSION

777,093. July 6, 1955.—Resilient Safety Device for Machinery, Dalmine, S.p.A., 19, Via Brera, Milan, and Carlo Montagna, Dalmine (Bergamo), Italy.

According to the invention, there is provided a resilient safety device, comprising a rigid box-like body having a base and side walls, the body being provided with a cover free to move towards the base of the body under the action of the load, and containing alternately disposed rigid and resilient elements having substantially plane and parallel opposite contacting faces, the elements being inclined to the direction of movement of the cover relative to the body. When in use the resilient safety device is mounted on the machine so that the direction of the



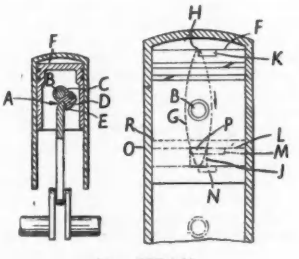
No. 777,093

load is the same as the direction of movement of the cover relative to the body. In the drawing *A* indicates a substantially box-shaped body having, for example, a rectangular base constituting, together with the cover *B*, a casing containing the resilient portion constituted by rectangular metal bars *C*, alternating with rubber cushions *D*. The bars are inclined at a small angle with respect to the line of action of force *E*. By effect of the force *E* having such a direction as will press the cover towards the box, the bars will tend to assume a greater inclination, this deformation being resisted by the reaction originated by the compression of the rubber cushions *D*, co-operating with the side walls of the box.—*June* 19, 1957.

INTERNAL COMBUSTION ENGINES

777,061. September 23, 1954.—Improvements in Engines, Alan Chadwick, P.O. Kajiado, Kenya Colony, East Africa.

The primary object of the invention is to provide improved drive transmitting mechanism between the crankshaft and piston, whereby the piston is caused to oscillate about its axis as well as to reciprocate. Referring to the drawing, the crankpin, crankshaft, and the big end of the connecting-rod of an internal combustion piston engine are of conventional design, but the small end indicated generally at *A* and the connection between this end and the gudgeon pin *B* are modified to give the necessary oscillation to the piston. The gudgeon pin extends through the piston generally at right angles to the axis of the crankshaft instead of being parallel to the crankshaft axis. The gudgeon pin receives a trunnion block *C* having a spigot member *D* whose axis intersects the gudgeon pin axis normally but at an angle of, say, 45 deg. to the axis of the crankpin and to the general longitudinal axis of the connecting-rod, which has an inclined end portion *E* journalled around the spigot *D*. As the crankshaft turns, the connection between the piston and the small end of the connecting-rod is such that the piston oscillates to a small degree so that any point on the piston takes an elongated elliptical path for each up-and-down stroke of the



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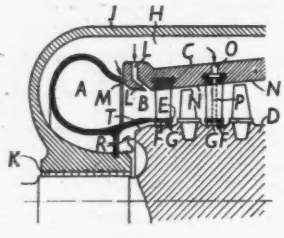
piston, which path is thus taken by a bevel step that may be formed at the edge *F* of the crown of the piston. The right-hand view indicates by dotted lines *G* the elliptical path taken by a point *H* on the crown of the piston. The actual elliptical path taken by the point is affected by the throw of the crank, by the length of the connecting-rod and by the inclination of the various pivotal axes. The designer can therefore cater for any desired control over the opening and closing of a port in the cylinder wall. In the example shown, the port is indicated by the square *J* and the step in the piston by the rectangle *K*, the step being a bevel step between the ends of the rectangle. It will be seen that when the piston is moving down in the cylinder bore and the upper edge of the piston has reached the level *L*, the upper edge

of the piston is flush with the upper edge of the port and the step in the piston is disposed wholly to the right-hand side of the port, so that the port is not yet in communication with the cylinder space above the piston. In this position the step is indicated at *M*. As the piston continues to move down, the port *J* becomes open to the cylinder space above the piston and the step *K* moves to the left across the port until at the lowermost position of the piston the step is in the position indicated at *N*, at which it is half-way across the port but disposed wholly below it. As the piston commences its upward or outward stroke the step continues to move to the left across the port. When the upper edge of the piston reaches the position *O* with the piston moving up, the step is in the position *P* at which it is in line with the port *J* and has its upper edge coincident with the upper edge of the port. The piston now has to move up by a distance equal to the depth of the step before the port is closed to the cylinder space above the piston. Thus, during its downward or inward stroke, the port *J* has not started to open by the time the upper edge of the piston reaches the level *L*, whereas during the outward or upward stroke of the piston the port will not be closed from the cylinder space until the upper edge of the piston has reached the level *R*.—*June* 19, 1957.

GAS TURBINES

776,847. May 13, 1955.—GAS-COOLED GAS TURBINE, Sulzer Freres, Société Anonyme, Winterthur, Switzerland.

The invention relates to gas turbines and methods of operating such turbines, in which a part of the boundary surface of the gas flow channel through the turbine is screened by a curtain of protective cooling gas against the hotter working medium, and in which a labyrinth seal is arranged in the gap between the shroud ring of a blade ring and the wall of the flow channel. As the drawing shows, the hot working medium of the turbine is supplied through an annular space *A* to a flow channel *B*. Stator blades are inserted into a casing *C* and the rotating blades on to the turbine rotor *D*. The stator blades are provided with shroud rings *E*, while the adjacent walls of the



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blade channel are provided with labyrinth sealing rings *F*. These rings form restrictions to gas flow between the walls and the shroud rings so that a gap is formed, *G*, at the inner ends of the stator blades. Protective cooling gas is supplied from a compressor driven by the gas turbine, into a space *H* surrounding the stator blade carrier and enclosed by the housing *J*. A labyrinth seal *K* is fitted between the housing and the turbine rotor shaft. A part of the cooling gas, in this case air, is led from the space *H* to the roots of the guide blades through the bores *L*, these bores also acting as metering devices. The effective area of the bores is so dimensioned that independently of the amount of protective gas flowing through the gap *M* between the blade carrier *C* and the wall of the annular channel *A*, which is liable to vary owing to thermal expansion, an adequate amount of protective gas is supplied for the satisfactory screening of the outer boundary surface *N* of the flow channel. A bore *O* leads from the space *H* to the root of each stator blade and each blade has a longitudinal bore *P* which opens into the labyrinth gap *G*. There are a greater number of labyrinth rings downstream than upstream of the bore *P*, so that in normal operation part of the protective gas issues from the labyrinth gap upstream of the blades. The cooling gas issuing from the downstream side of the gap forms a blanket over the adjacent surface of the rotor and passes along the rotor, cooling the inner ends and roots of the blades on the rotor ring. The supply of air to the gap between the rotor and first row of stator blades is provided as follows : the gas passes from the space *H* through the metering channel *R* into the collecting chamber *S*, from whence it is led by the annular gap *T* into the labyrinth gap *G*. The pressure of the cooling gas only needs to be a little above that of the working medium at this point, so that part of the protective gas passes into the flow channel *B* upstream of the guide blades, whereas the remainder flows through the labyrinth gap *G* on account of the lower pressure downstream of the blades. It is important to avoid the use of one bore *P* or channel *R* and to distribute these bores around the whole circumference and preferably each guide blade will have a bore *P*.—*June* 12, 1957.

Technical Reports

Three-Dimensional Wind-Tunnel Tests of a 30 deg. Jet Flap Model. J. Williams, M.Sc., Ph.D., and A. J. Alexander, B.Sc., Aerodynamics Division, N.P.L. A.R.C. Current Paper No. 304. H.M. Stationery Office. Price 8s.—As a first investigation of finite aspect ratio effects in relation to the jet flap scheme, pressure plotting experiments were made on a small-scale model, with a 12½ per cent thick wing section, already tested under two-dimensional conditions at the N.G.T.E. The spanwise distribution of "pressure lift" loading induced by T.E. blowing was evaluated by chordwise integration of the surface static pressures, and followed closely that which would be expected for a conventional wing at incidence (without T.E. blowing). The total lift, drag and pitching moments were derived for values of jet momentum coefficient C_J up to 2 at wing incidences between −5 deg. and 20 deg., and up to 5 at zero incidence, by summing the corresponding integrated pressure forces and jet reaction components.

Turbulent Diffuser Flow. By B. S. Stratford. Current Paper No. 307. H.M.S.O. Price 7s. 6d.—Exact solutions of the equations of motion are possible for various types of diffuser. Application is restricted to that part of each diffuser in which the velocity profile has attained a constant shape. The solutions are expressed in terms of the distribution of the mixing length, which effectively is the length of the mean free path of the turbulence.

In particular the solutions yield the value of the critical angle of a diffuser for just avoiding flow separation ; this value is proportional to the square of the turbulence level. If, on the other hand, the critical angle is known, use of the solutions in reverse allows an accurate assessment of the turbulence level. Thus, if for the circular cone diffuser the critical total angle is 10 deg., the turbulence estimated would be 30 per cent greater than that existing in the flow through a parallel pipe.

Even in a flow which is diffusing rapidly a narrow wake becomes attenuated by the turbulence it produces. A large central wake, as from the bullet of a fan or turbine, is attentuated if the flow is of moderate diffusion angle. However, the solutions suggest that a central wake, especially if produced by a high-turbulence grid, could be used to advantage for preventing flow separation in diffusers of very large angle.

If side jets are used for flow control at large diffuser angles and if the jets are required to persist a long distance downstream, the jet velocity at any axial station would need to exceed twice the mean velocity for the cross section.

British Standards Institution

All British Standard Specifications can be obtained from the Sales Department of the Institution at 2, Park Street, London, W.1.

IRON AND STEEL FOR COLLIERY CAGE SUSPENSION GEAR, TUB AND MINE CAR DRAW GEAR, AND COUPLINGS AND ROPE SOCKETS.

No. 2772 : 1956.—Part 1, Wrought Iron (Price 6s.) ; Part 2 : Wrought Steel (Price 4s.).—These standards were authorised by the Iron and Steel Industry Standards Committee and are part of a general revision of British Standards for iron and steel for colliery haulage and winding equipment.

Parts 1, 2 and a third part to be published shortly deal with wrought iron, wrought steel and steel castings respectively, and cover the requirements of the mining industry in respect of materials for load-carrying components of haulage and cage suspension gear.

The first two parts are each divided into sections covering general requirements and specific requirements. The general requirements deal with dimensional and weight tolerances, the marking and provision of material for testing, and tensile and bend test requirements. The specific requirements for Part 1 cover "Best Yorkshire," "Special" grade, and Grade A wrought iron ; and the specific requirements for Part 2 cover 25/30-ton carbon steel, 1·5 per cent manganese steel and 50/70 -ton tensile steel.

Appendices include tables of metric equivalents and information on the forms of British Standard test pieces required for the purpose of the standard. The appendix to Part 2 also contains information on "ruling sections."

METHODS FOR THE ANALYSIS AND TESTING OF COAL AND COKE

No. 1016 : 1957 : Part 1, "Total Moisture of Coal." Price 3s. 6d. This revised standard deals expressly with the analysis and testing of coal and coke, and its companion standard, B.S. 1017, now under revision, will deal with the collection and preparation of samples for analysis.

The standard will be published in separate parts, each dealing with a particular group of analyses. Where a method for a particular group of analyses for coke differs widely from that for coal it will be published as a separate part ; but where the modifications for coke are slight they will be given as separate sections of the same part.

The present part of the standard deals with the determination of the moisture in the coal "as sampled." Each of its sections relates to a sample of given particle size and applicable methods are specified in sub-sections. Details of air drying and reduction in particle size have been excluded, since they will be fully treated in the revision of B.S. 1017.

In the distillation method for the ¼in sample, toluene has been substituted for petroleum distillate of 150–180 deg. Cent. boiling range, as it has been found that petroleum distillate can give higher results due, possibly, to the evolution of water of hydration from the mineral matter or to the decomposition of the coal at elevated temperatures.

METHODS OF TEST FOR AIR FILTERS USED IN AIR CONDITIONING AND GENERAL VENTILATION

No. 2831 : 1957. Price 7s. 6d. This standard applies to methods of testing air filters and does not specify standards of performance.

In the "methylene blue efficiency test" described the methylene blue dust used contains only fine particles. Because of this, the test is a severe one and a filter exposed to normal atmospheric impurities would be expected to show higher efficiencies than those indicated by the test results. Nevertheless, the test is considered to provide a fair comparison of the relative efficiencies of different filters when used under similar atmospheric conditions. Among the requirements in this section of the standard are those for the test rig, calculation of results, and apparatus for the production of test dust. The foreword to the standard points out that atmospheric pollution differs from the standard methylene blue dust cloud, in that it may contain some coarse particles in addition to the fine ones ; this small proportion of larger particles is believed to be mainly responsible for the clogging of a filter, with consequent increase of resistance and termination of its useful life. It is because the life of a filter may be as important as its efficiency that the methylene blue test is supplemented by a test for dust-holding capacity which employs two grades of coarse dust. Among the requirements in this section of the standard are those for the test rig, ancillary equipment and for reporting results.

Forthcoming Engagements

Secretaries of Institutions, Societies, &c., desirous of having notices of meetings inserted in this column, are requested to note that, in order to make sure of their insertion, the necessary information should reach this office not later than a fortnight before the meeting. In all cases the TIME and PLACE at which the meeting is to be held should be clearly stated.

ASSOCIATION OF SUPERVISING ELECTRICAL ENGINEERS

Sat., July 6.—OXFORD, READING AND DISTRICTS BRANCH : Visit to the Atomic Energy Research Establishment, Harwell.

BRITISH INTERPLANETARY SOCIETY

Thurs. to Sat., July 18 *to* 20.—JOINT MEETING WITH THE COLLEGE OF AERONAUTICS : College of Aeronautics, Cranfield, Symposium on "High Altitude and Satellite Rockets."

CHEMICAL SOCIETY

Mon. to Tues., July 8 *to* 9.—Queen's Building, Queen Mary College, London, Symposium on "Solvent Effects and Reaction Mechanism."

Thurs. to Fri., July 11 *to* 12.—Chemistry Department, University of Glasgow, Symposium on "Recent Advances in the Chemistry of Terpenoid Compounds."

INSTITUTE OF THE MOTOR INDUSTRY

Sat. to Sat., Aug. 24 *to* 31.—St. Catharine's College, Cambridge, Eleventh Annual Summer School.

INSTITUTE OF PETROLEUM

Tues., July 9.—26, Portland Place, London, W.1, "Hydrocarbons from Petroleum," Frederick D. Rossini, 4.30 p.m.

INSTITUTE OF ROAD TRANSPORT ENGINEERS

Thurs., July 18.—LONDON BRANCH : Day visit to the factory of de Havilland Aircraft Company, Ltd., Hatfield, Herts.

INSTITUTION OF MECHANICAL ENGINEERS

Wed., July 17.—S. WALES BRANCH : Visit to Rank Precision Industries (B.A.F.), Ltd., Mitcheldean, Gloucester.

Wed., July 24.—N.W. BRANCH : Visit to Calder Hall Nuclear Power Station.

Sat., Aug. 31.—S. BRANCH : Whole-day visit to the pumping stations of the Mid-Wessex Water Company, Frimley, Surrey.

INSTITUTION OF NAVAL ARCHITECTS

Tues. to Thurs., July 9 *to* 11.—Summer Meeting in Bristol.

PLASTICS INSTITUTE

Fri., July 19.—Conference Room, Gallery, National Hall Olympia, London, W.14, Annual General Meeting, 12 noon.

ROYAL METEOROLOGICAL SOCIETY

To-day, July 5.—Department of Natural Philosophy, University of Glasgow, Summer Meeting.